NBS CIRCULAR 546

Effective Radio Ground-Conductivity Measurements in the United States

UNITED STATES DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

PERIODICALS OF THE NATIONAL BUREAU OF STANDARDS

The National Bureau of Standards is engaged in fundamental and applied research in physics, chemistr mathematics, and engineering. Projects are conducted in thirteen fields: electricity, optics and metrolog heat and power, atomic and radiation physics, chemistry, mechanics, organic and fibrous materials, met lurgy, mineral products, building technology, applied mathematics, electronics, and radio propagatio The Bureau has custody of the national standards of measurement and conducts research leading to t improvement of scientific and engineering standards and of techniques and methods of measuremer Testing methods and instruments are developed; physical constants and properties of materials are det mined; and technical processes are investigated.

JOURNAL OF RESEARCH

Internationally known as a leading scientific periodical, the Journal presents research papers by auth ities in the specialized fields of physics, mathematics, chemistry, and engineering. Complete details the work are presented, including laboratory data, experimental procedures, and theoretical and mat matical analyses. Annual subscription: domestic, $5.50; foreign, $6.75.

TECHNICAL NEWS BULLETIN

Summaries of current research at the National Bureau of Standards are published each month in t Technical News Bulletin. The articles are brief, with emphasis on the results of research, chosen on t basis of their scientific or technologic importance. Lists of all Bureau publications during the preced month are given, including Research Papers, Handbooks, Applied Mathematics Series, Building M terials and Structures Reports, and Circulars. Each issue contains 12 or more two-column pages; ill trated. Annual subscription: domestic, $1.00; foreign, $1.35.

BASIC RADIO PROPAGATION PREDICTIONS

The Predictions provide the information necessary for calculating the best frequencies for communicati between any two points in the world at any time during the given month. The data are important to users of long-range radio communications and navigation, including broadcasting, airline, steamship, a wireless services, as well as to investigators of radio propagation and ionosphere. Each issue, coverin period of one month, is released three months in advance and contains 16 large pages, including pertin charts, drawings, and tables. Annual subscription: domestic, $1.00; foreign, $1.25.

Order all publications from the Superintendent of Documents
U. S. Government Printing Office, Washington 25, D. C.

UNITED STATES DEPARTMENT OF COMMERCE • Sinclair Weeks, *Secretary*
NATIONAL BUREAU OF STANDARDS • A. V. Astin, *Director*

Effective Radio Ground-Conductivity Measurements in the United States

R. S. Kirby, J. C. Harman, F. M. Capps, and R. N. Jones

National Bureau of Standards Circular 546
Issued February 26, 1954

For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.
Price 65 cents

Contents

	Page
1. Introduction	1
2. Description of data	1
3. Maps	2

Effective Radio Ground-Conductivity Measurements in the United States

R. S. Kirby, J. C. Harman, F. M. Capps, and R. N. Jones

Maps are presented showing the results of effective ground-conductivity measurements made by various broadcasters and consulting engineers throughout the United States. The need for such detailed maps has been indicated by the lack of reliability inherent in the use of general-area conductivity maps and by studies of the correlation of effective ground-conductivity measurements with surface soil conditions. Over 7,000 radials are shown on the maps, and provisions have been made for entering new measurements, as the results become available, for possible future publication. Due to the complexity of ground-wave propagation over an inhomogeneous earth, the determination of effective ground conductivity over a given radial strictly applies only at the frequency at which the measurements were made.

1. Introduction

In 1947 the National Bureau of Standards began a program of cataloging measurements of effective ground conductivity as obtained from the files of the Federal Communications Commission. By 1953, a total of 7,237 such ground-conductivity determinations made at 621 broadcast stations in the 540 to 1,600-kc portion of the spectrum had been collected. A study was made of the relationship between effective ground conductivity and surface soil composition. The study showed some association of ground conductivity with soil type, but so little that its use in predicting future values of ground conductivity for given soil type generally yields too wide a range of values to be sufficiently precise. Previous effective ground-conductivity maps have been prepared on the assumption that the values of effective ground conductivity are fairly highly associated with soil types. However, the use of such maps has shown them to be inaccurate in many cases.

It is the purpose of this circular to present, in map form, a compilation of the accumulated effective ground-conductivity data showing the locations of the radials over which the measurements were made, the frequencies and call letters of the transmitters, and the values of effective ground conductivity associated with each radial.

2. Description of Data

Although both the conductivity and the dielectric constant of the ground are important in ground-wave radio propagation, it is important to note that, at the frequencies involved in these measurements, ground conductivity has, by far, the greater effect upon the received field strength, and the dielectric constant has but little effect. It is only at the higher frequencies that the dielectric constant becomes important and must be considered.

The method employed by the standard broadcasters and consulting engineers to determine effective ground conductivity involves a process of curve fitting, using calculated ground-wave field strength versus distance curves such as those presented by the Federal Communications Commission.[1] It will not be treated in detail here. In general, field-strength measurements are made along at least eight radials from a broadcast transmitter, or sometimes along more radials, depending upon the complexity of the horizontal radiation pattern of the transmitting antennas. At least 18 to 20 field-strength measurements are made along each radial, which when corrected for power are plotted versus distance and compared with the calculated ground-wave field-strength-versus-distance curves. The value of ground conductivity associated with the calculated curves most nearly fitting the measured data is taken as the value of effective ground conductivity for that radial. In some cases, where it appears apparent from the data that there is a rather abrupt change in ground conductivity, two or more values of effective ground conductivity are resolved by a process such as the equivalent-distance method described by Kirke.[2]

[1] Federal Communications Commission, Standards of good engineering practice concerning standard broadcast stations, U. S. Government Printing Office, Washington, D. C. (1938–48).

[2] J. L. Kirke, Calculation of ground-wave field strength over a composite land and sea path, J. Inst. Elec. Engrs. (London) part III, 96 53 (January 1949).

In an inhomogeneous medium, such as the ground, it is important to bear in mind that the depth of penetration varies considerably with frequency as well as with ground constants. The depth of penetration, defined as the depth at which the magnitude of the electric vector in the medium is a given percentage of its magnitude at the surface, is deeper at the lower frequencies and with higher values of the dielectric constant and lower values of conductivity. Because the characteristics of the ground may vary considerably with depth, the values of effective ground conductivity presented herein strictly apply only at the frequencies at which the measurements were made.

3. Maps

Special sectional maps have been prepared employing Albers equal-area projection, in which the linear distance scale is maintained constant. Each map covers 5 degrees of latitude and 5 degrees of longitude. A total of 48 of these sectors cover the entire United States. Figure 1 is an index map showing the location of each of the sectional maps superimposed on a United States map. The number in the corner of each square gives the order in which the sectional maps are arranged. In several cases large numbers of measurements were made in relatively small areas, and, to avoid confusion, several sectional maps of the same area have been prepared in order to accommodate all the measurements. The letters a, b, c, etc., denote cases in which more than one map is used. There are 81 sectional maps presented in this Circular, covering the 48 different sectors shown on the index map.

The maps have been prepared by using a scale such that sufficient detail can be shown, while keeping the number of maps to a practical minimum. One unavoidable consequence of using relatively small area maps for this presentation is that the radials around the edges of the maps frequently run into the next map. Effective ground conductivities are expressed in millimhos per meter, following the practice of the Federal Communications Commission. Where more than one value of conductivity has been assigned to a particular radial, the numbers shown indicate the appropriate value of effective ground conductivity for that portion of the path.

In tabulating, plotting, and drafting such a large amount of data, it seems quite probable that some errors have occurred. It is requested that anyone noting such errors bring them to the attention of the authors. As the results of new measurements become available, these will be incorporated in the master set of maps kept on file at the Central Radio Propagation Laboratory of the National Bureau of Standards in Boulder, Colo., and at the appropriate time, consideration will be given to the method for making the revised maps available.

The assistance of the staff of the Federal Communications Commission in making available from their files the data used in this report is greatly appreciated. Acknowledgment is made to Holmes S. Moore and to Rex B. Simms, former members of the staff of the Central Radio Propagation Laboratory of the National Bureau of Standards, for their assistance in collecting the ground-conductivity data and in preparing the maps

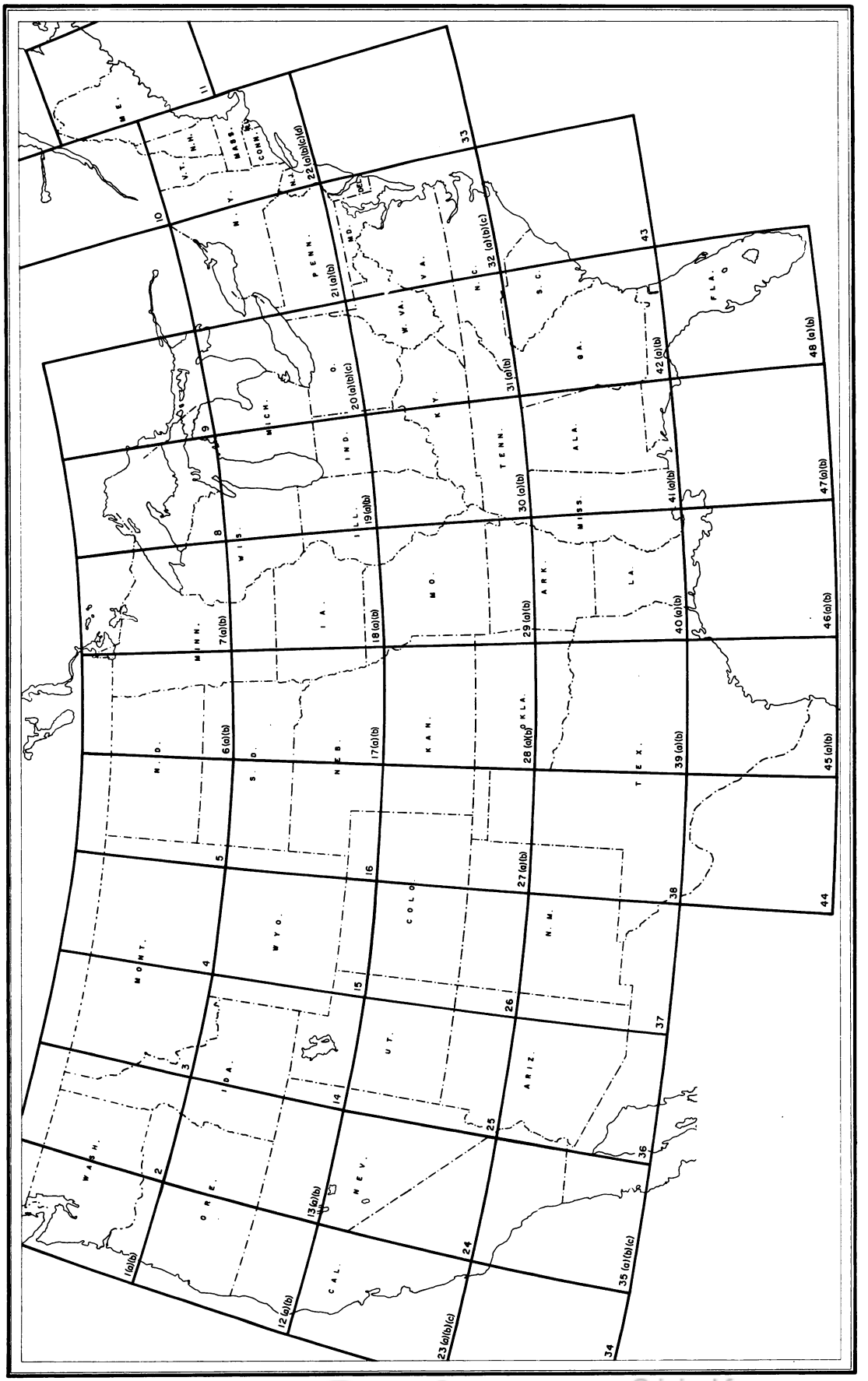
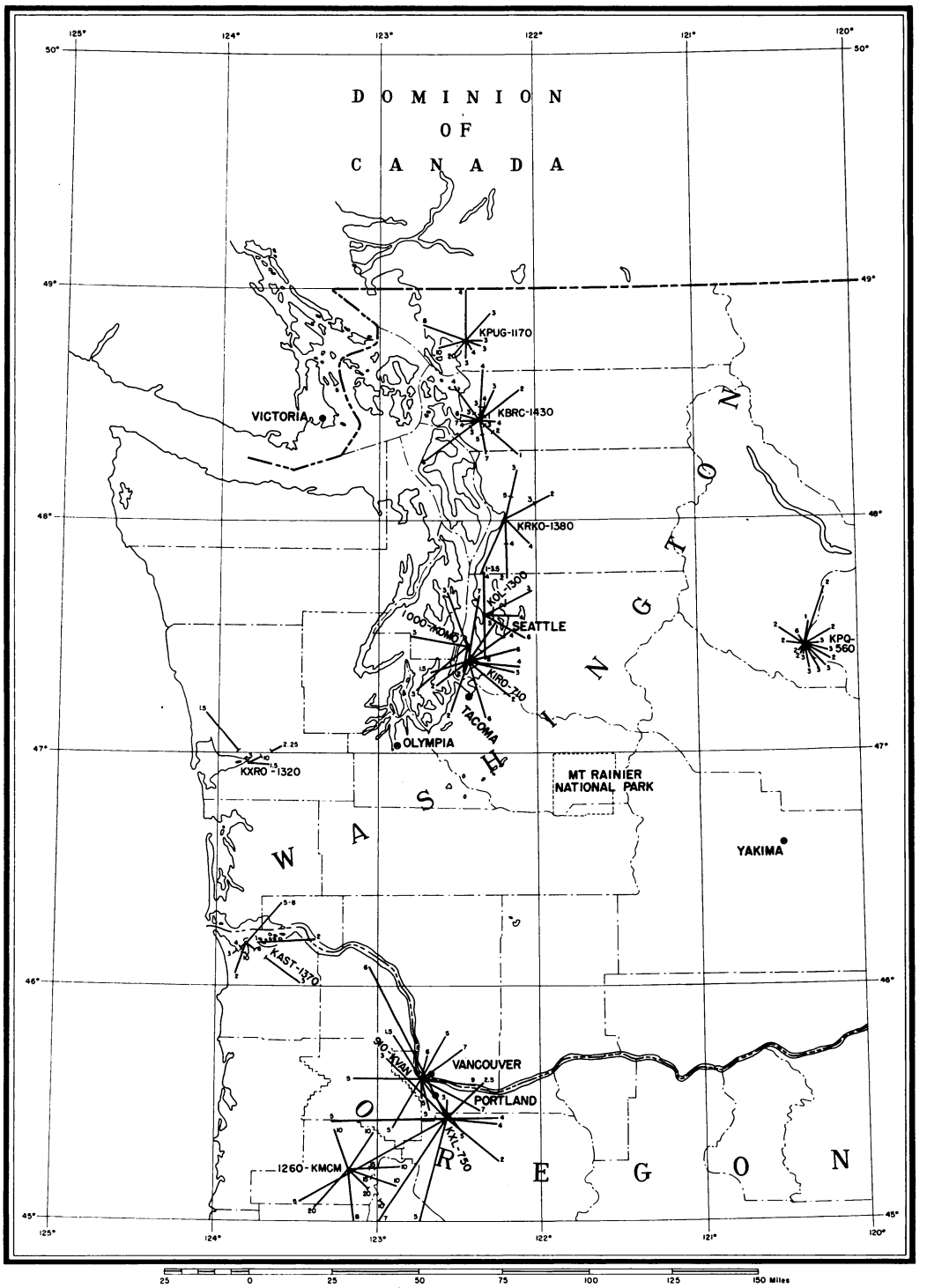
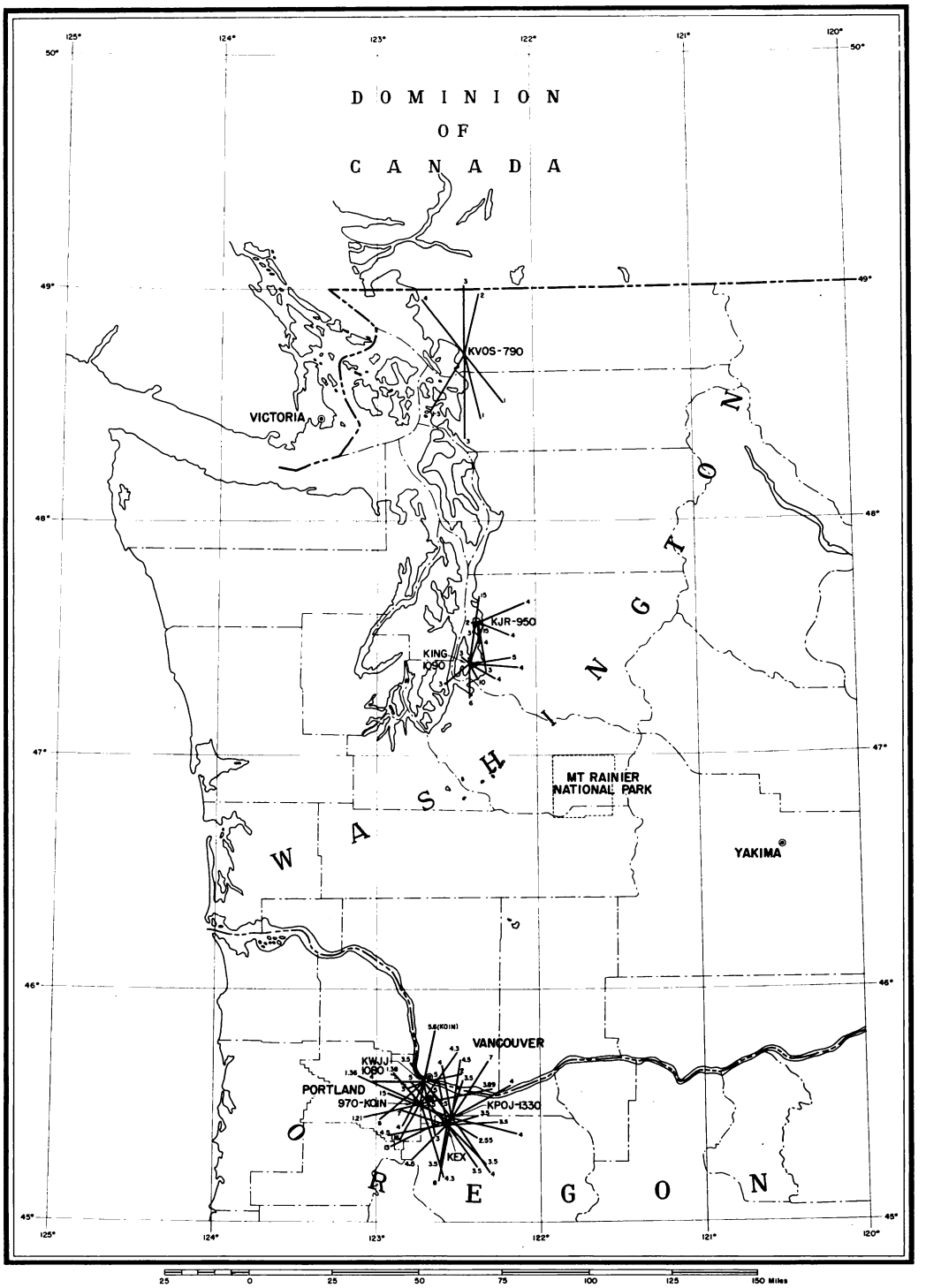


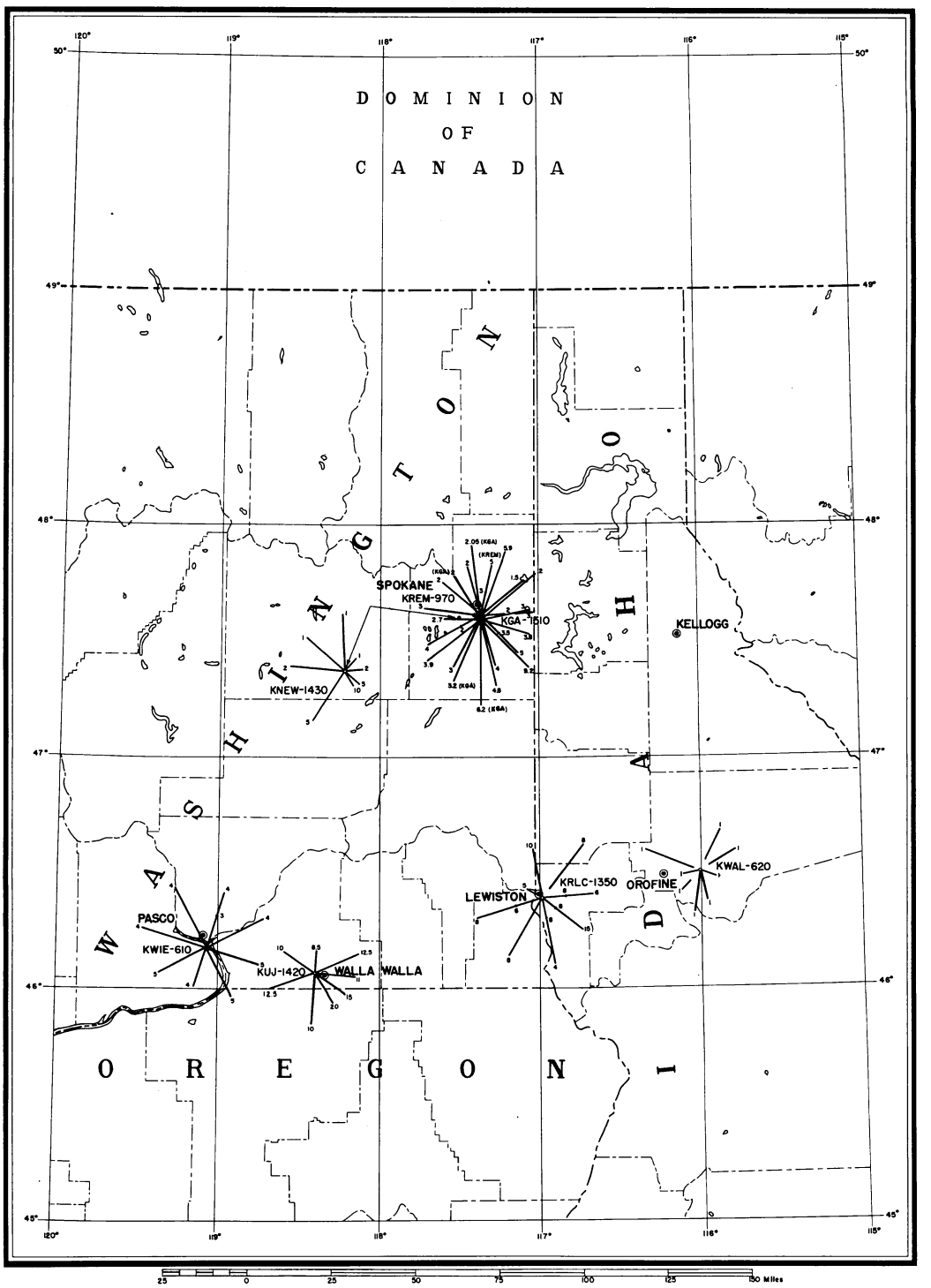
FIGURE 1. *Index to effective radio ground conductivity maps for the United States.*



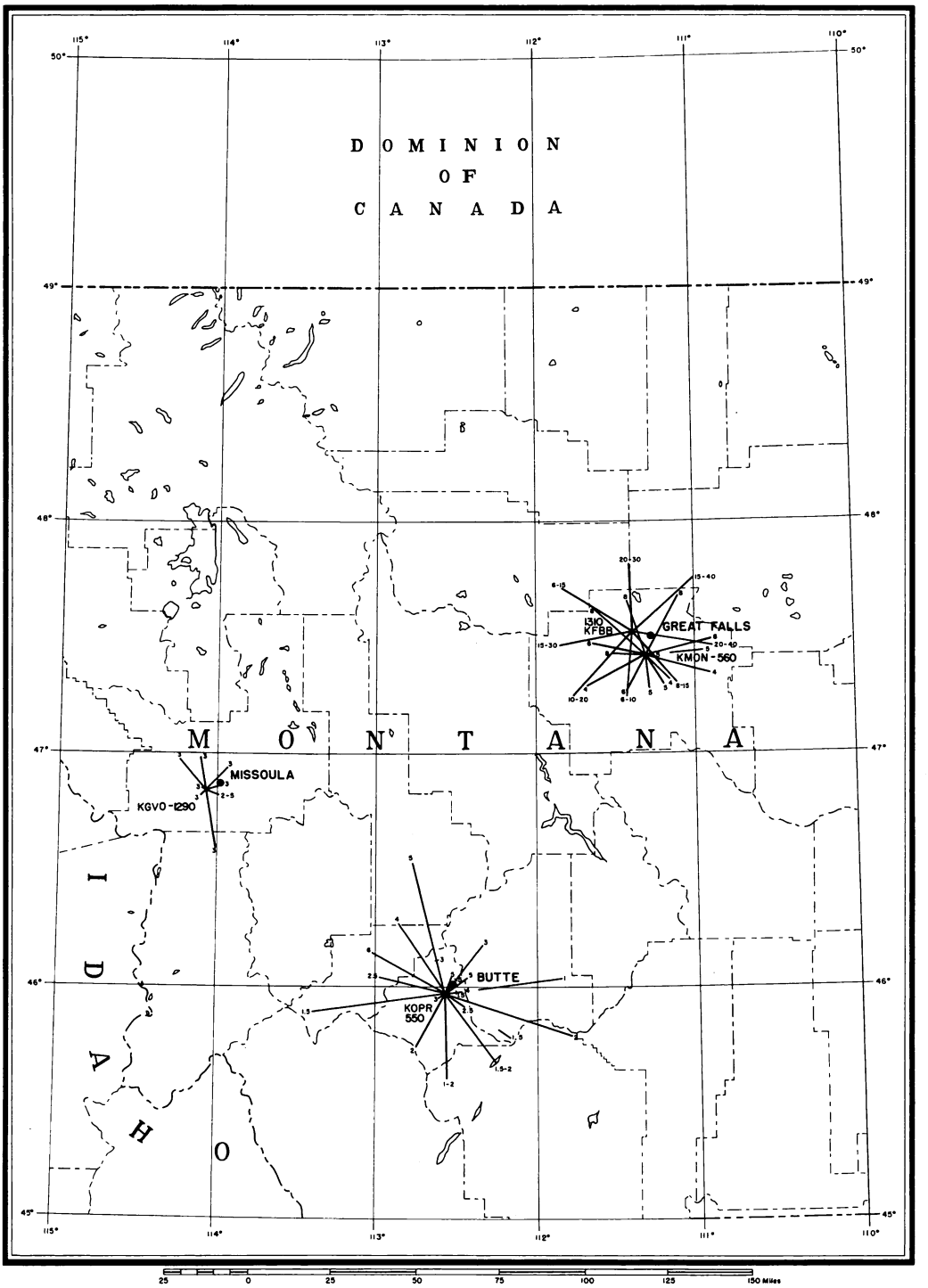
Map 1a.



MAP 1b.

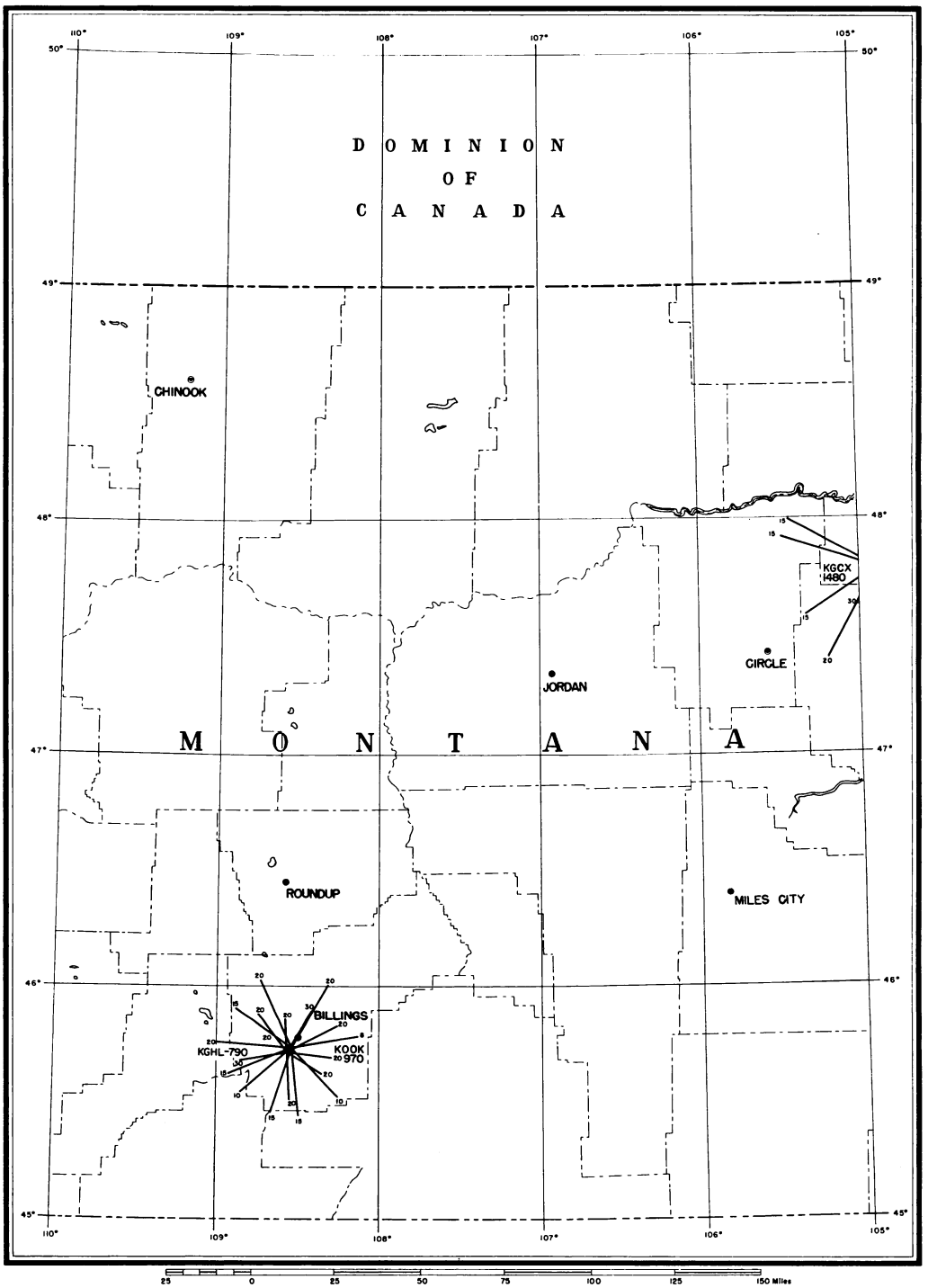


MAP 2.

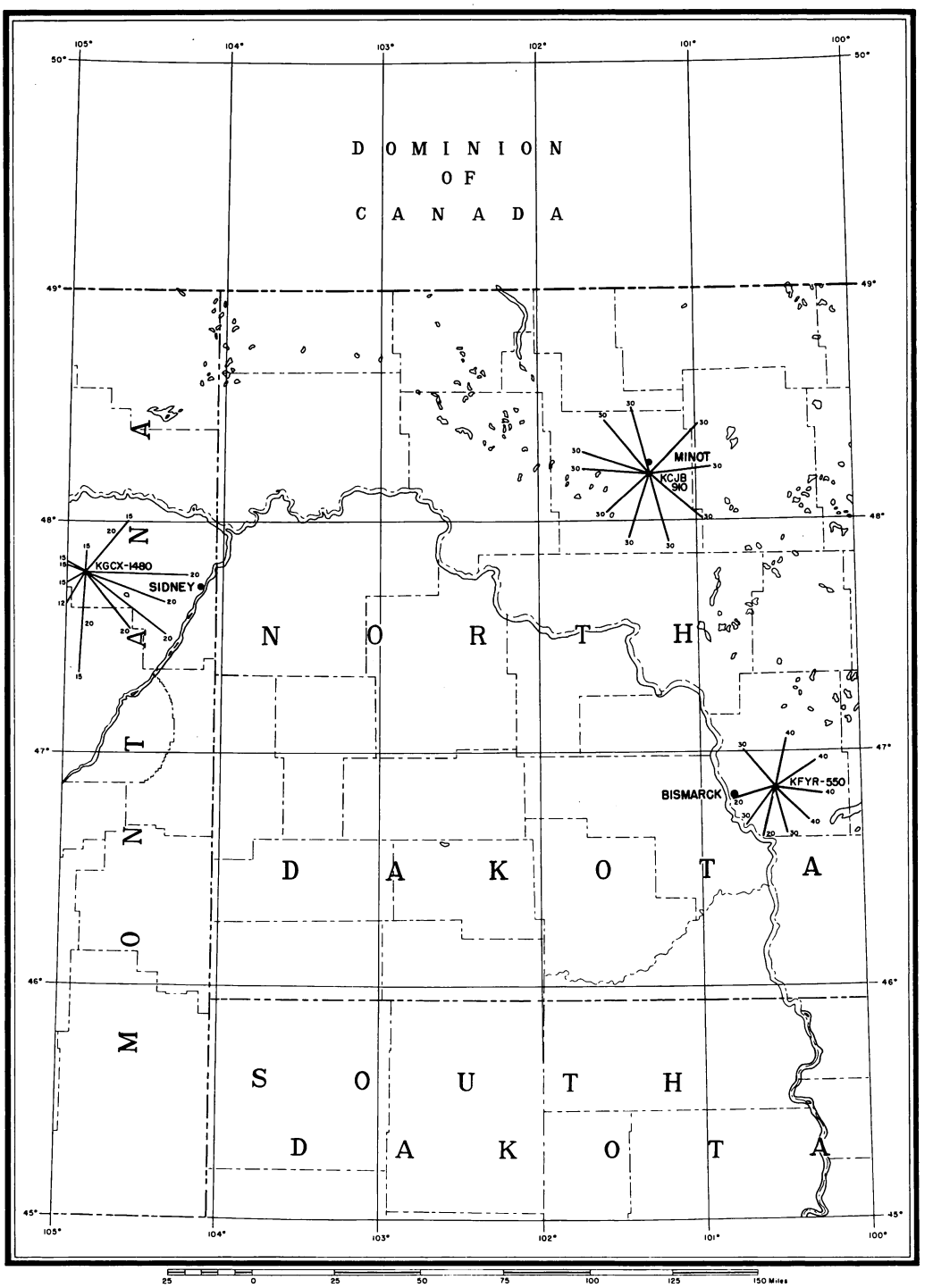


MAP 3.

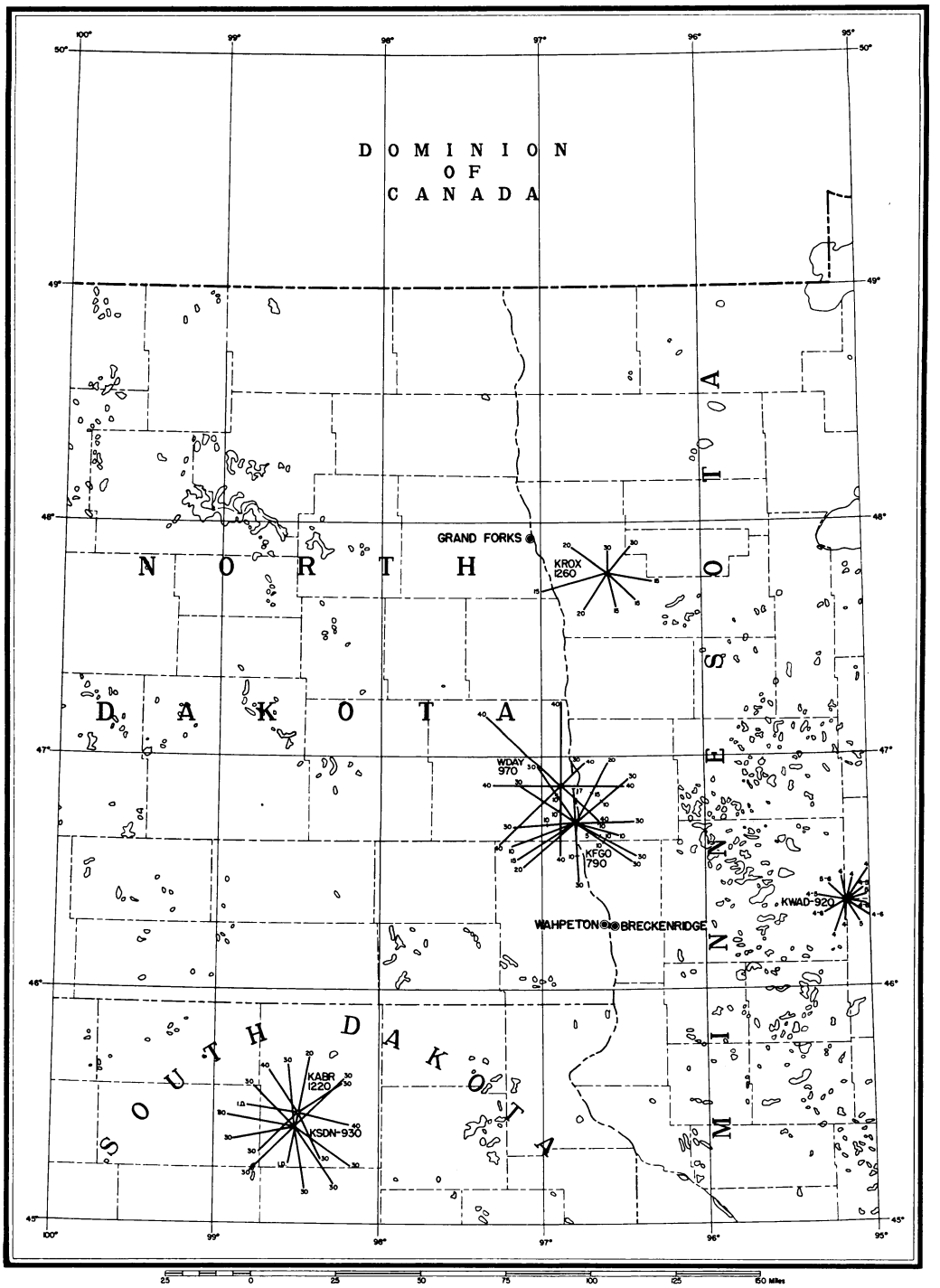
282270 O - 54 - 2



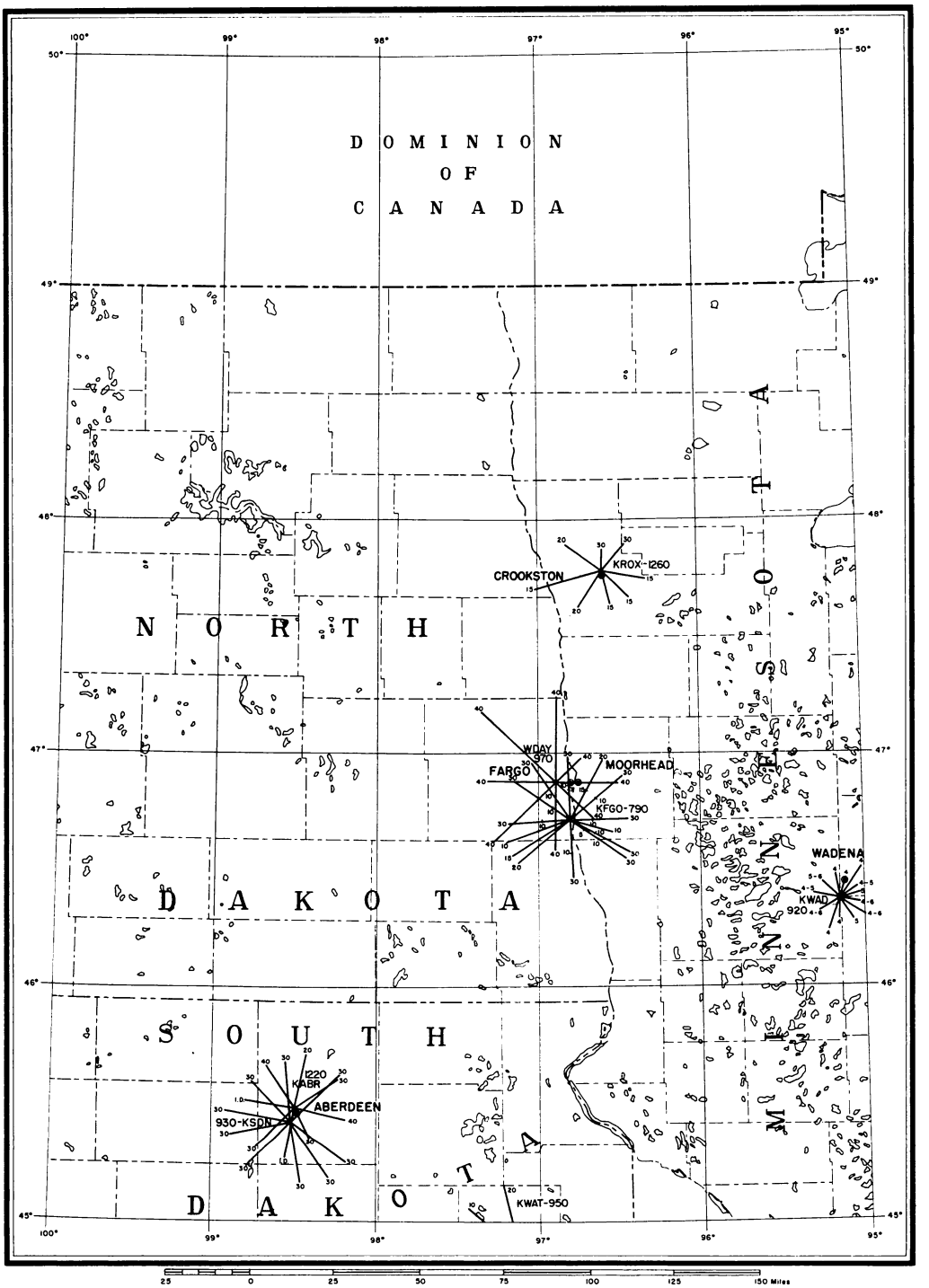
Map 4.



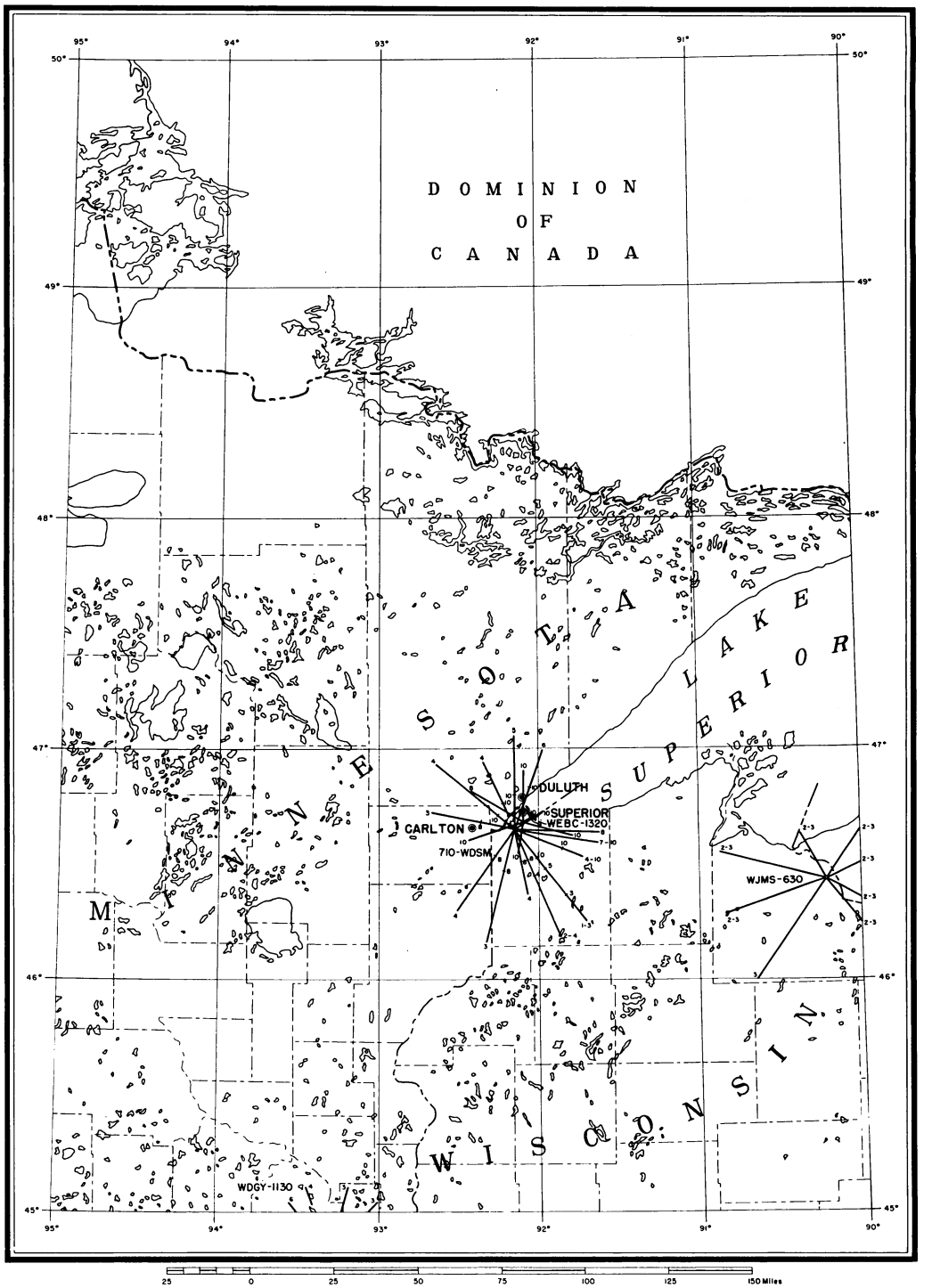
MAP 5.



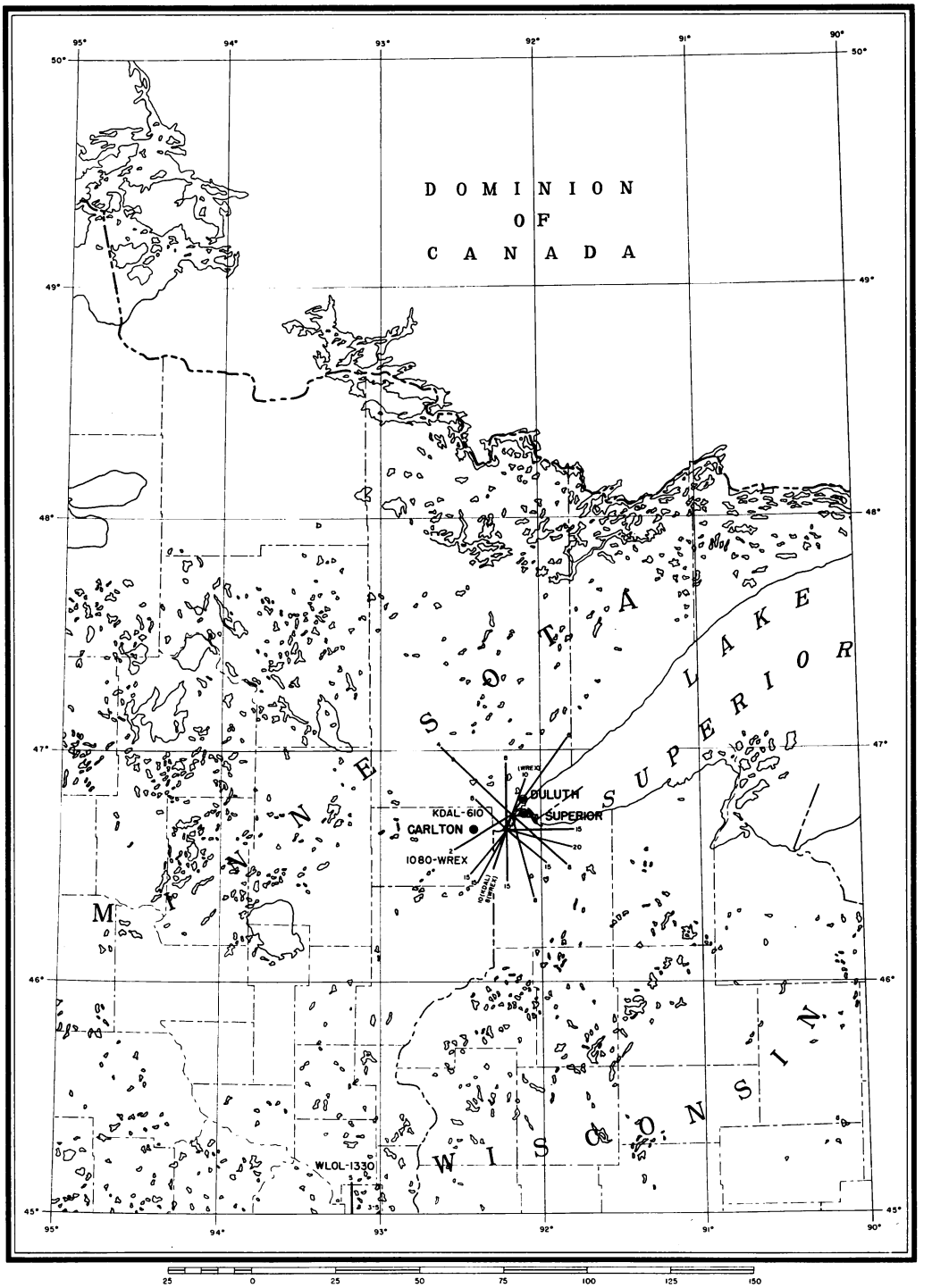
Map 6a.



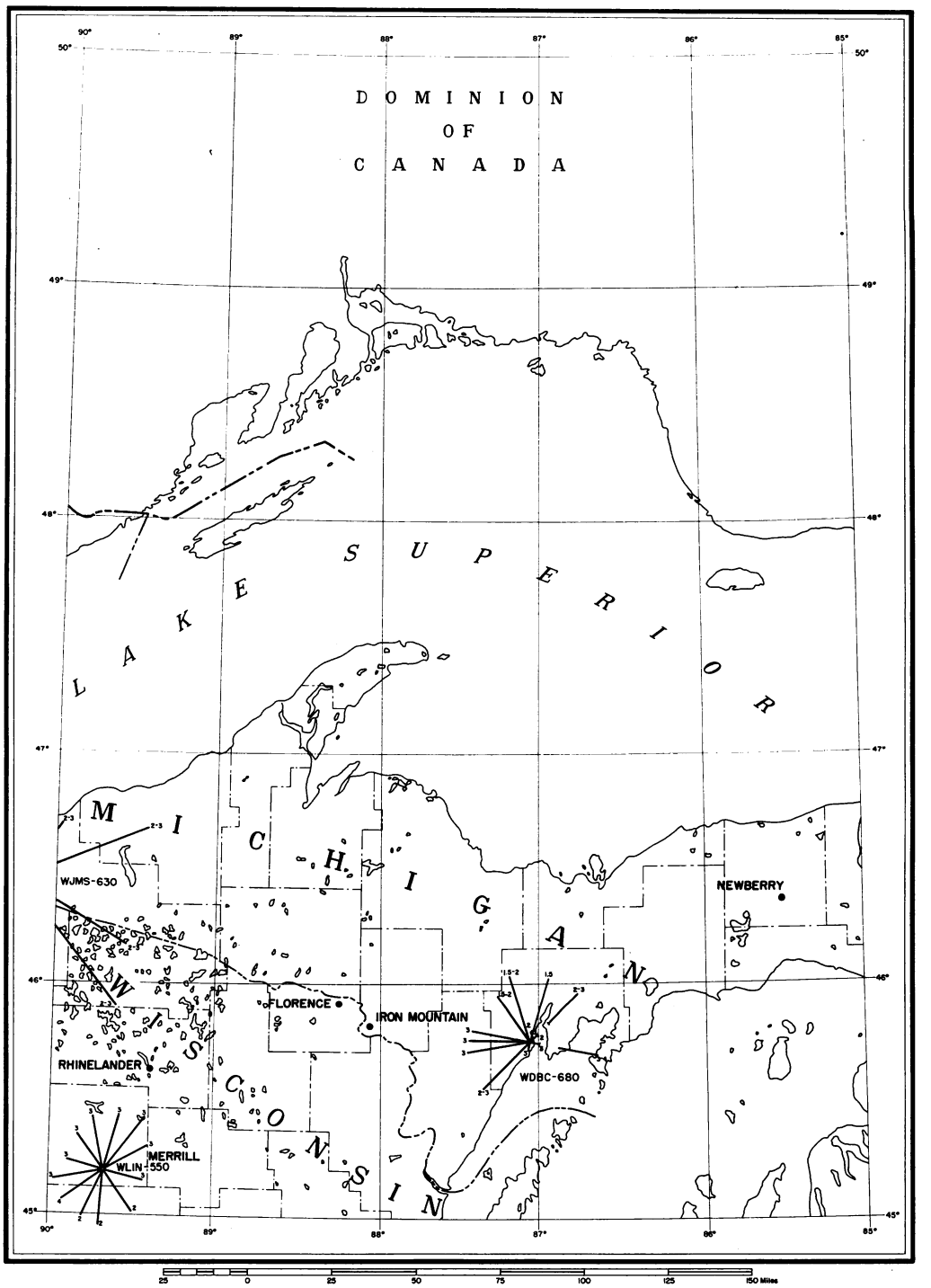
MAP 6b.



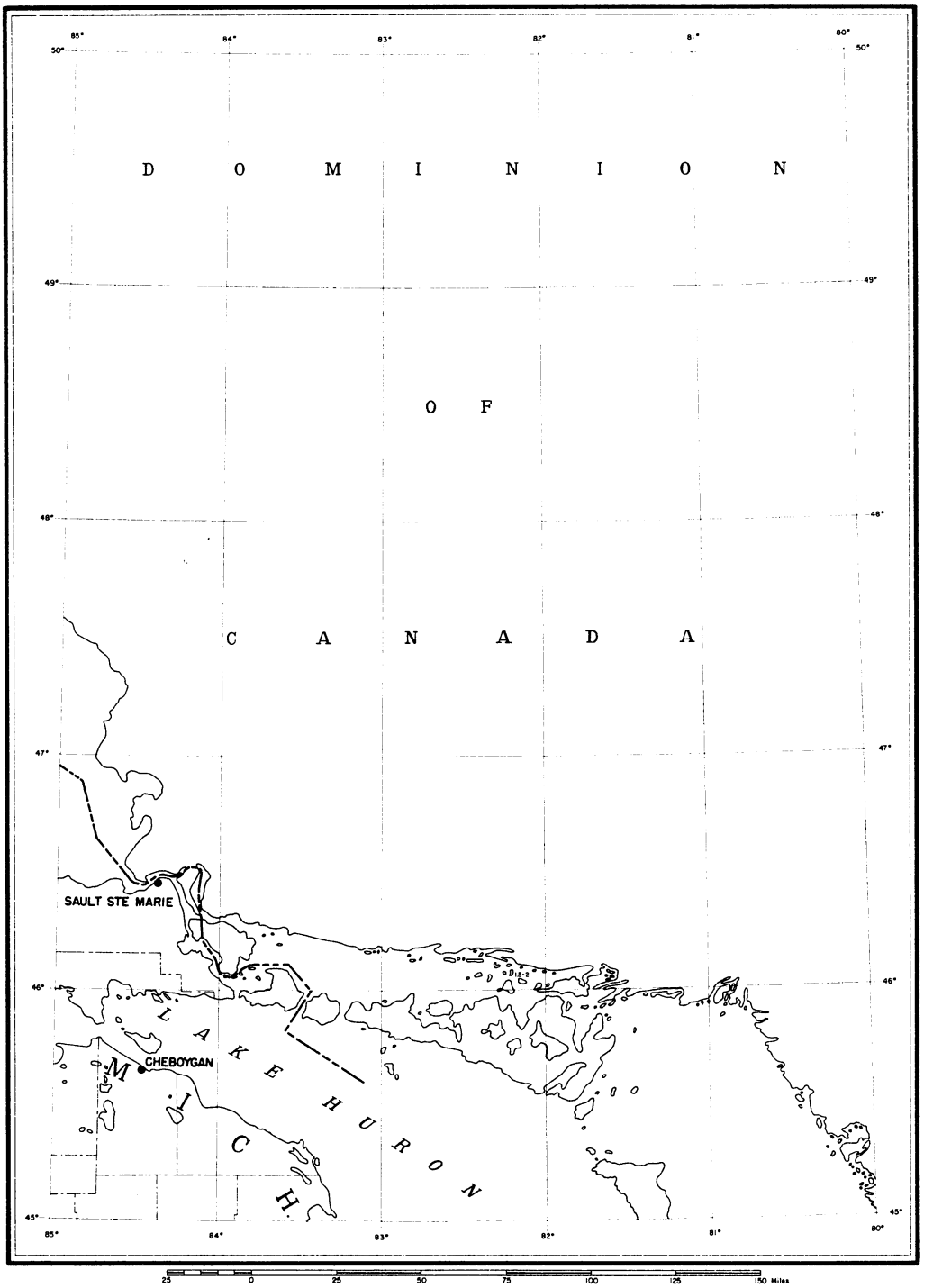
MAP 7a.



MAP 7b.

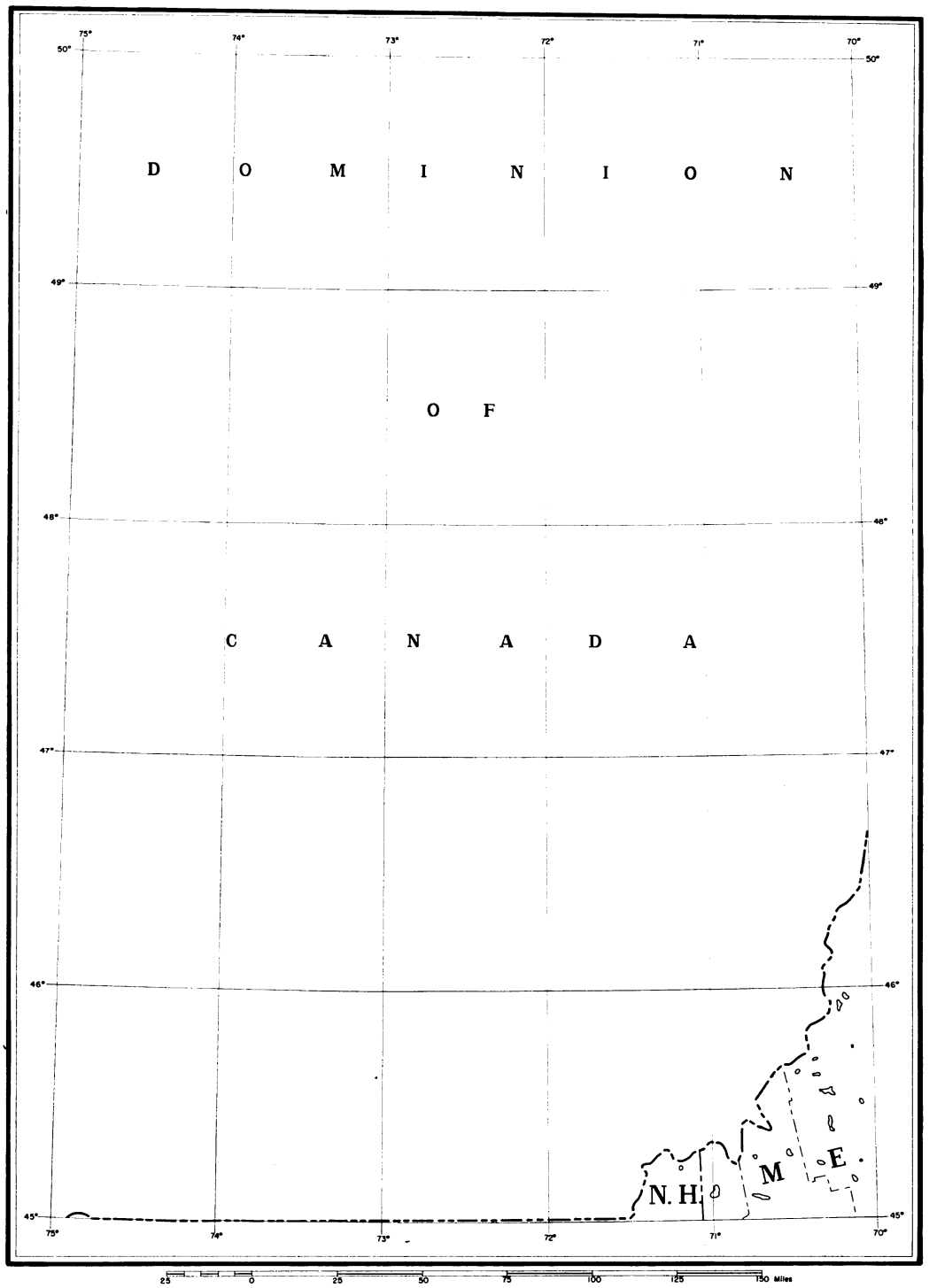


MAP 8.

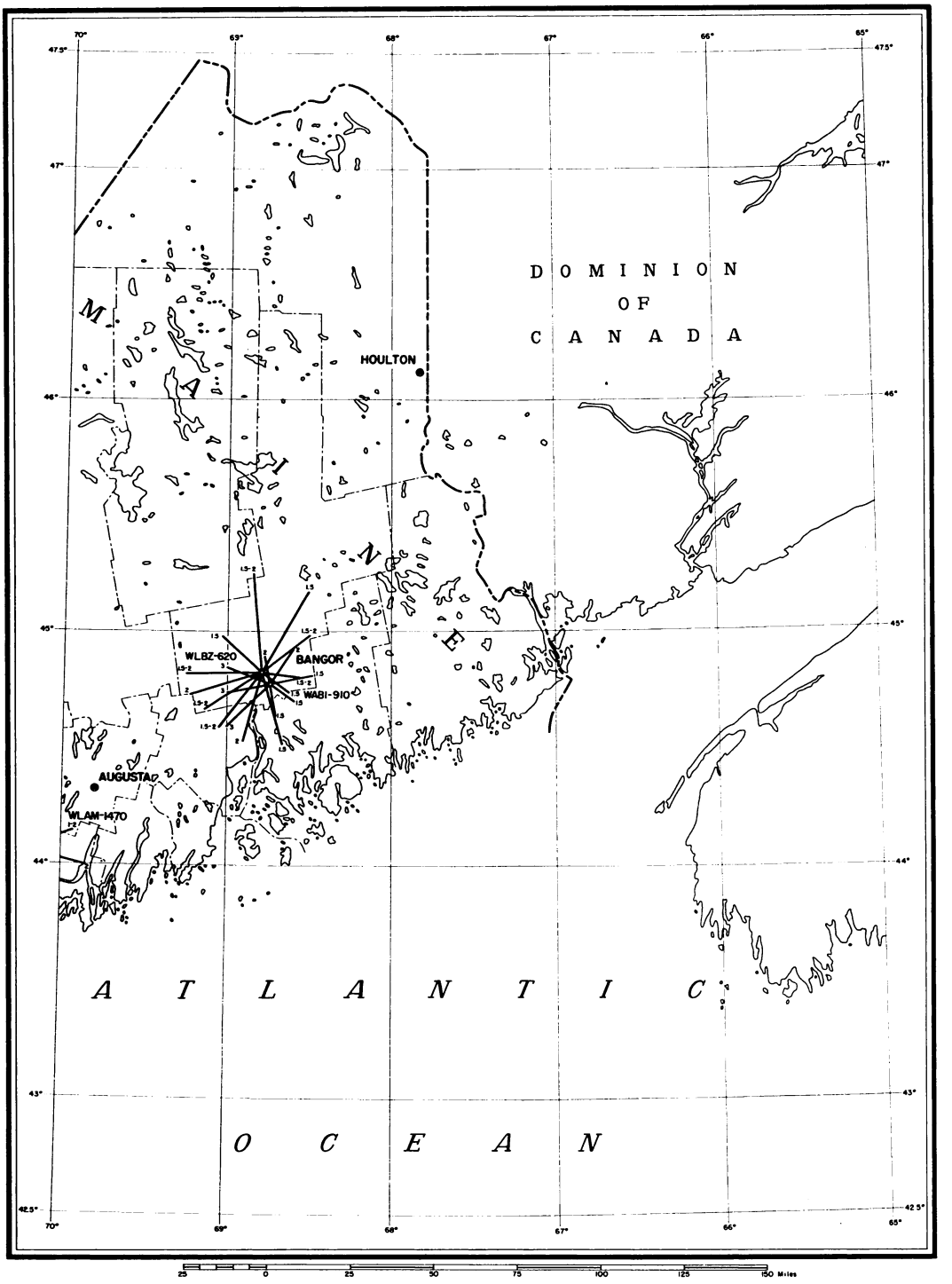


MAP 9.

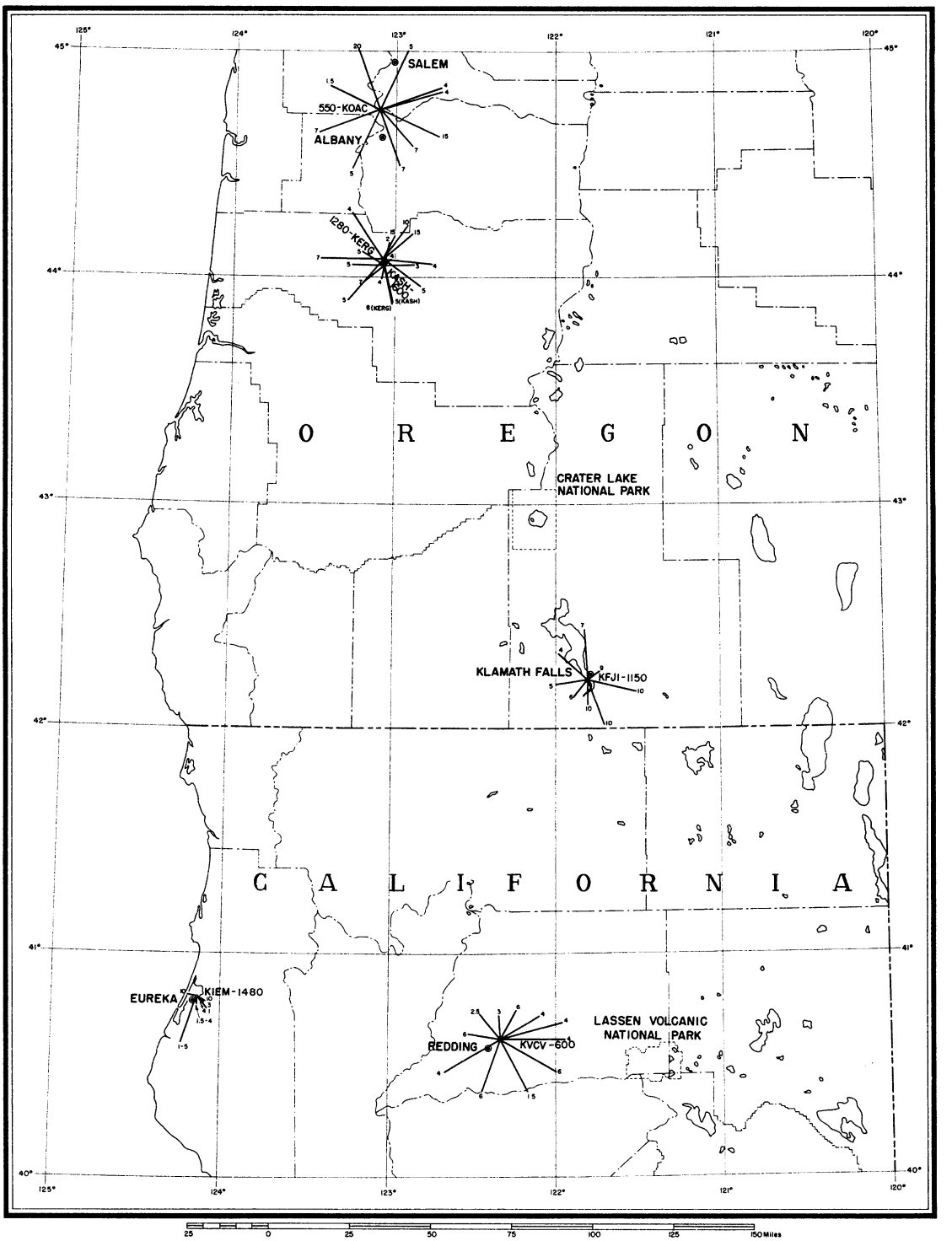
282270 O - 54 - 3



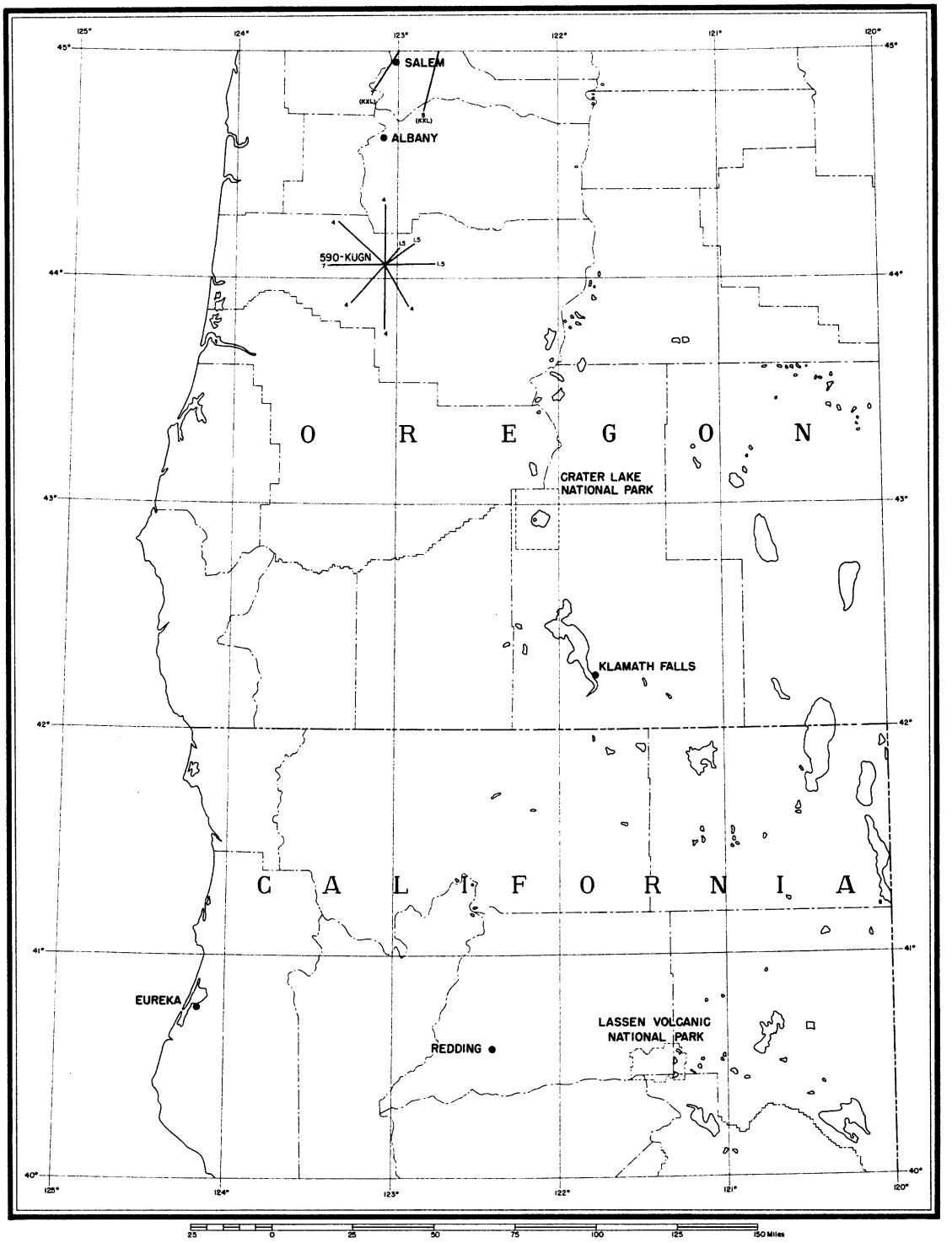
MAP 10.



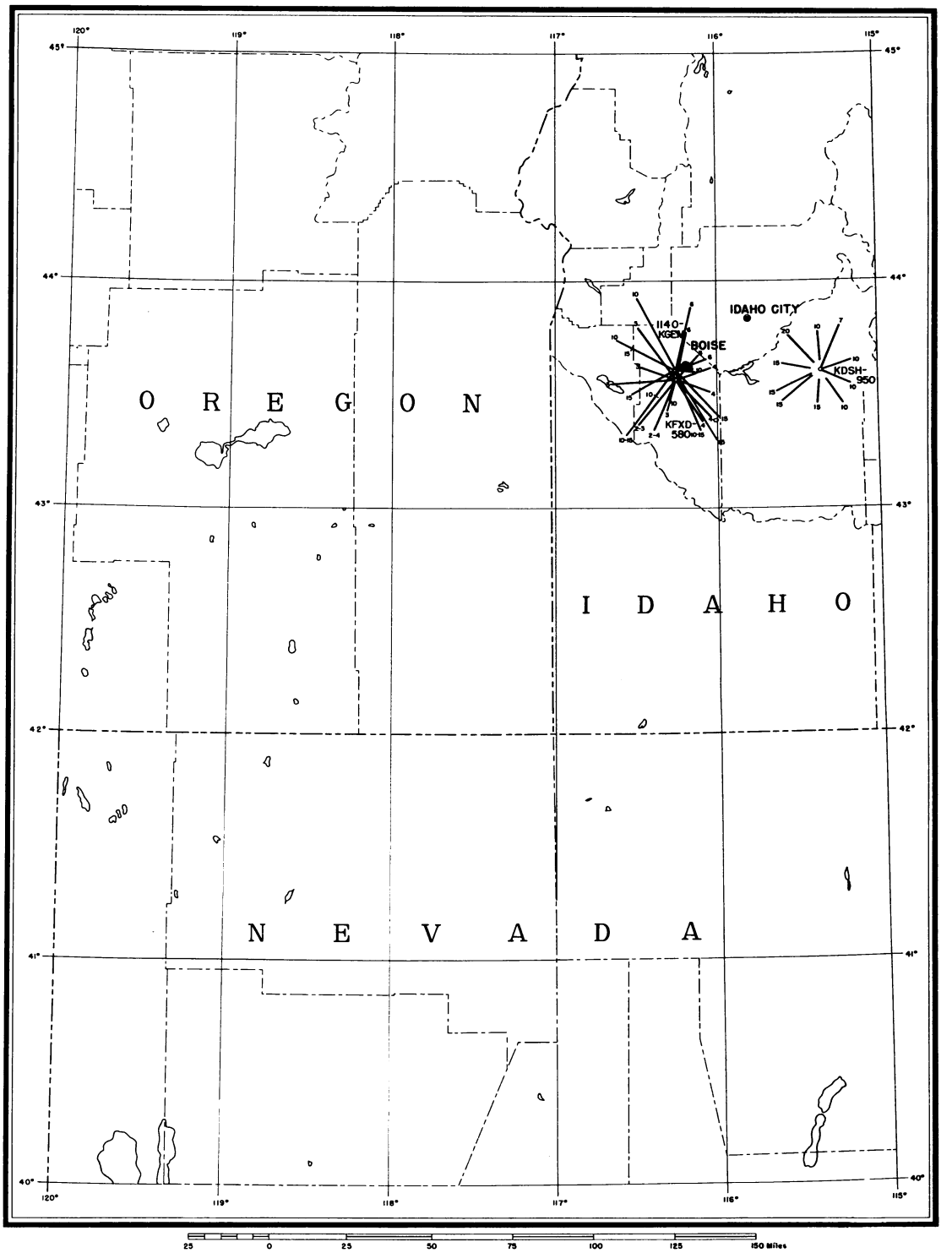
MAP 11.



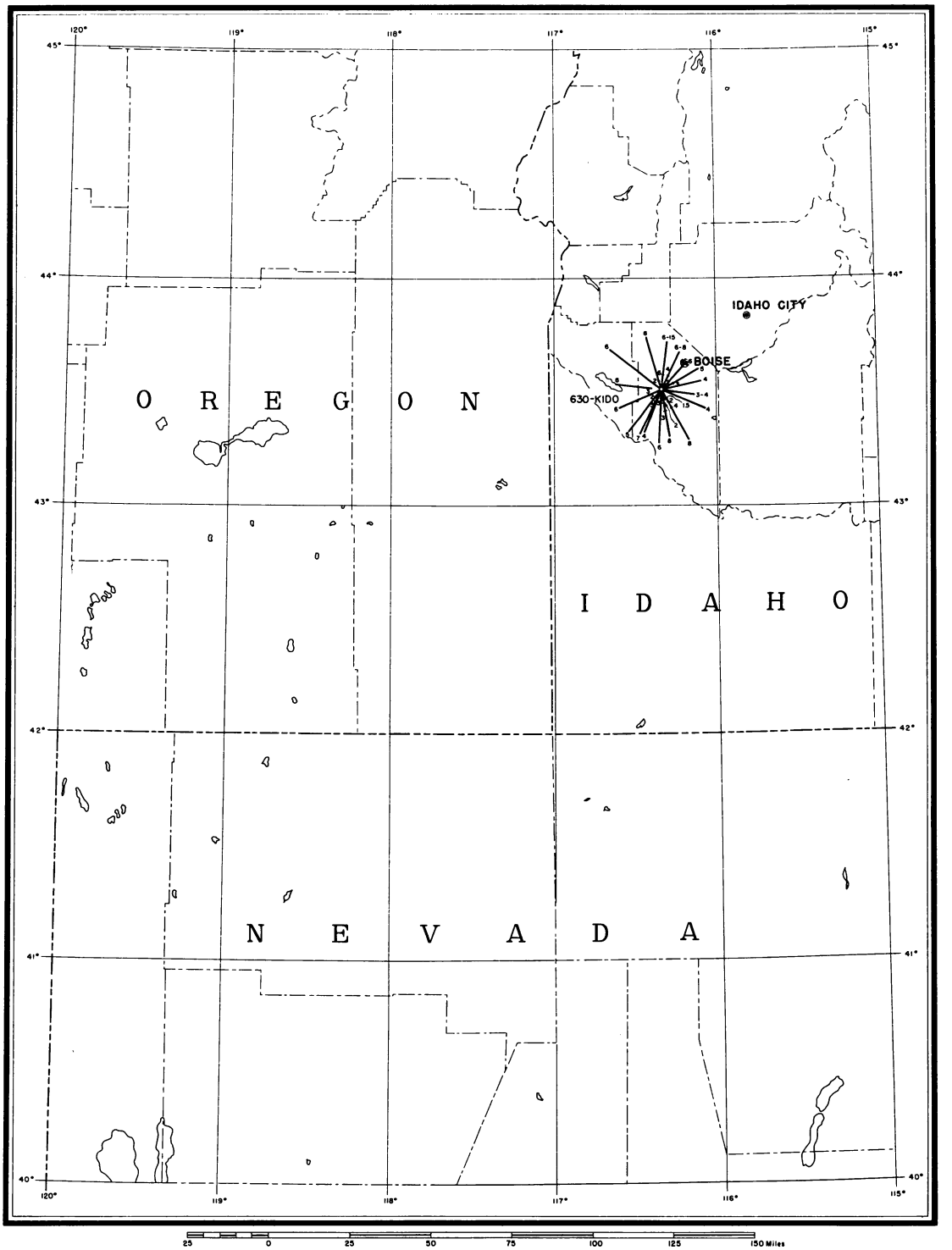
MAP 12a.



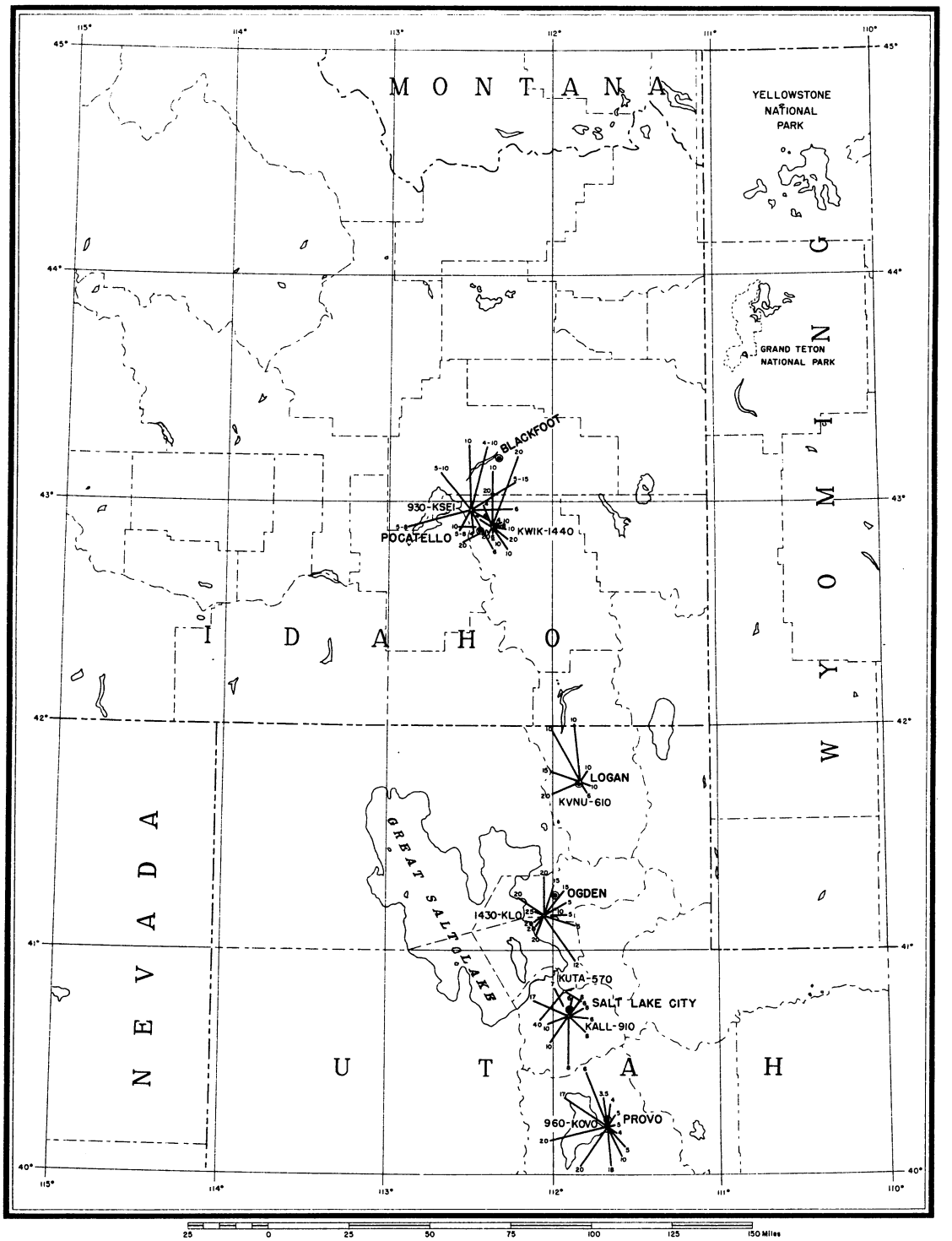
MAP 12b.



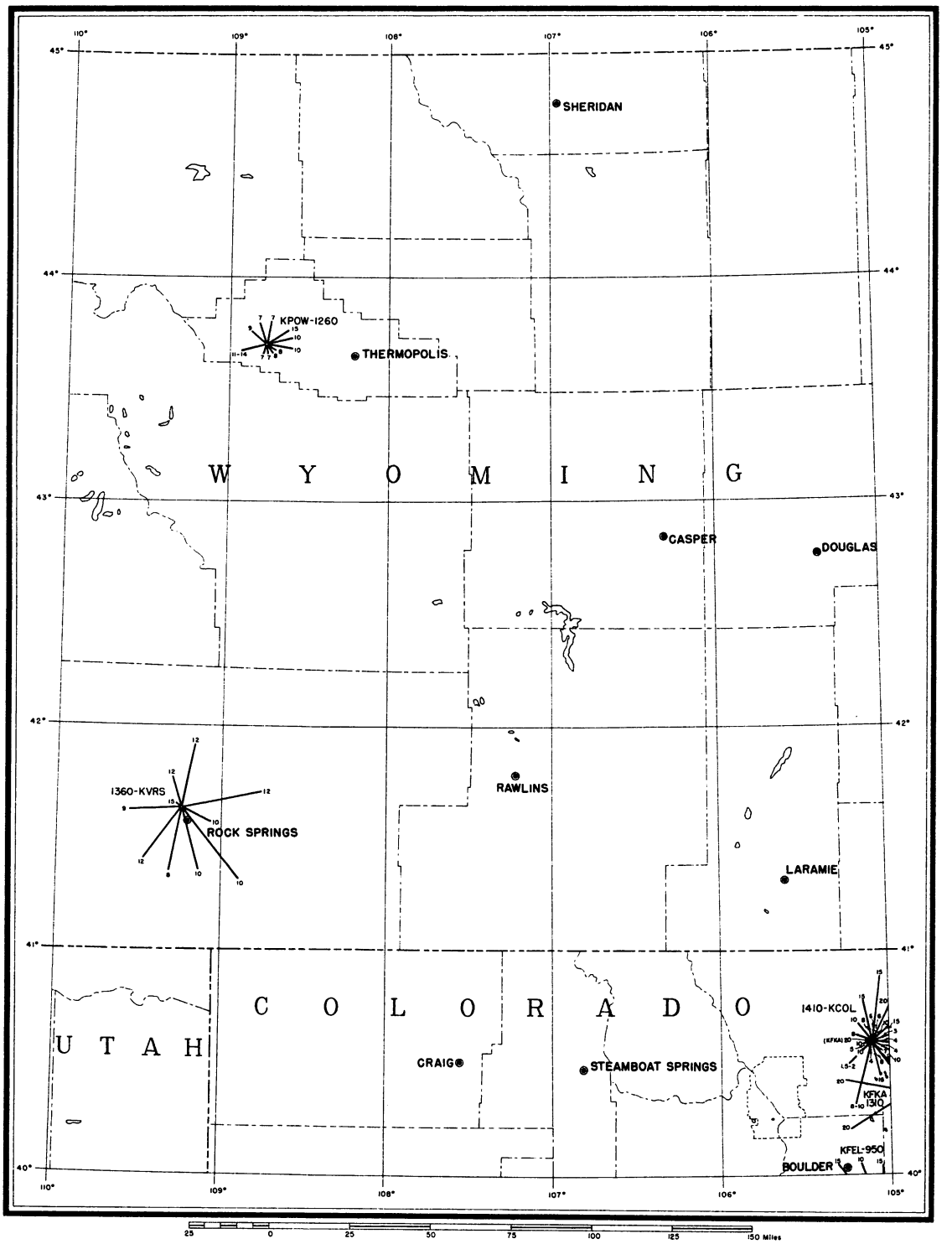
Map 13a.



MAP 13b.

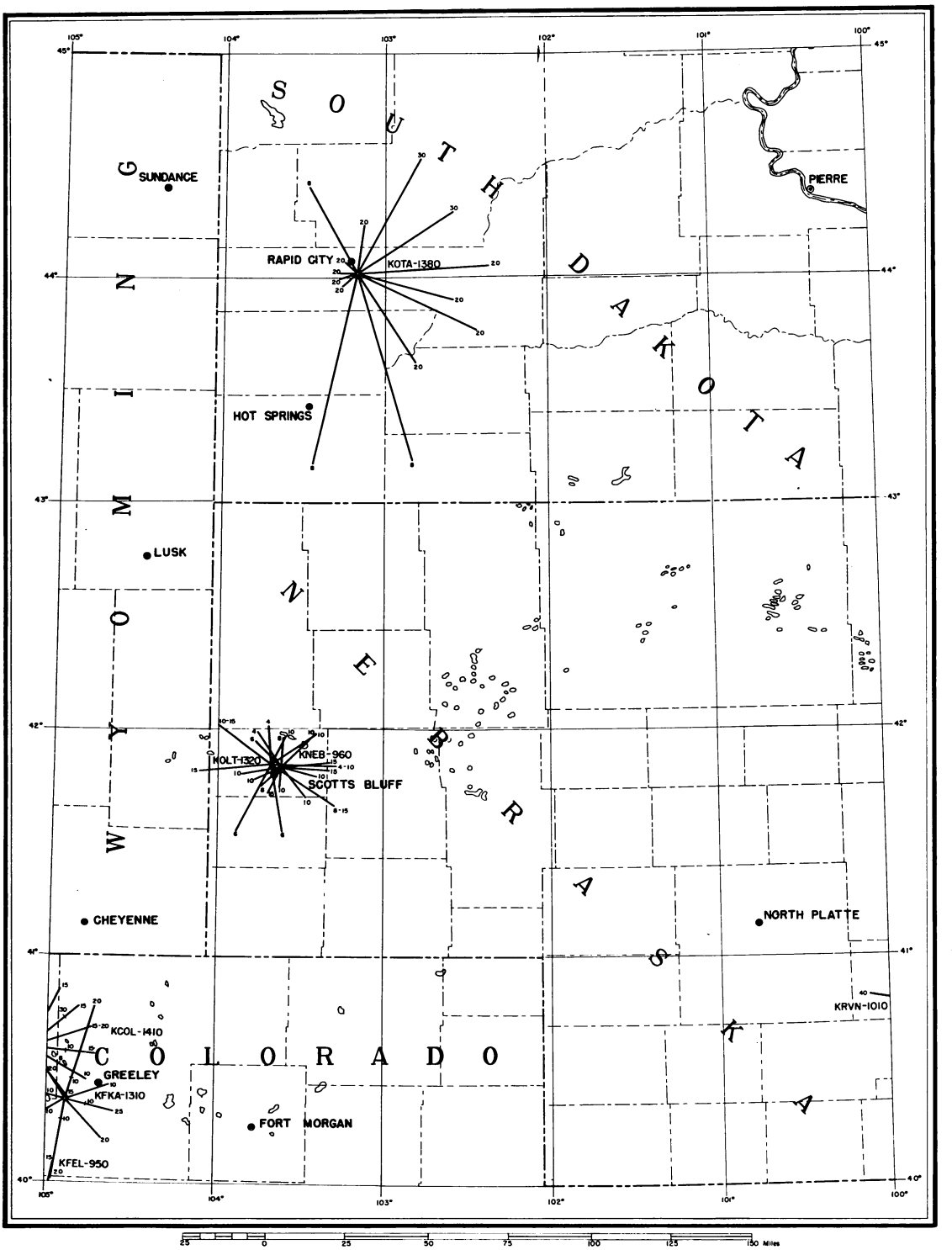


MAP 14.

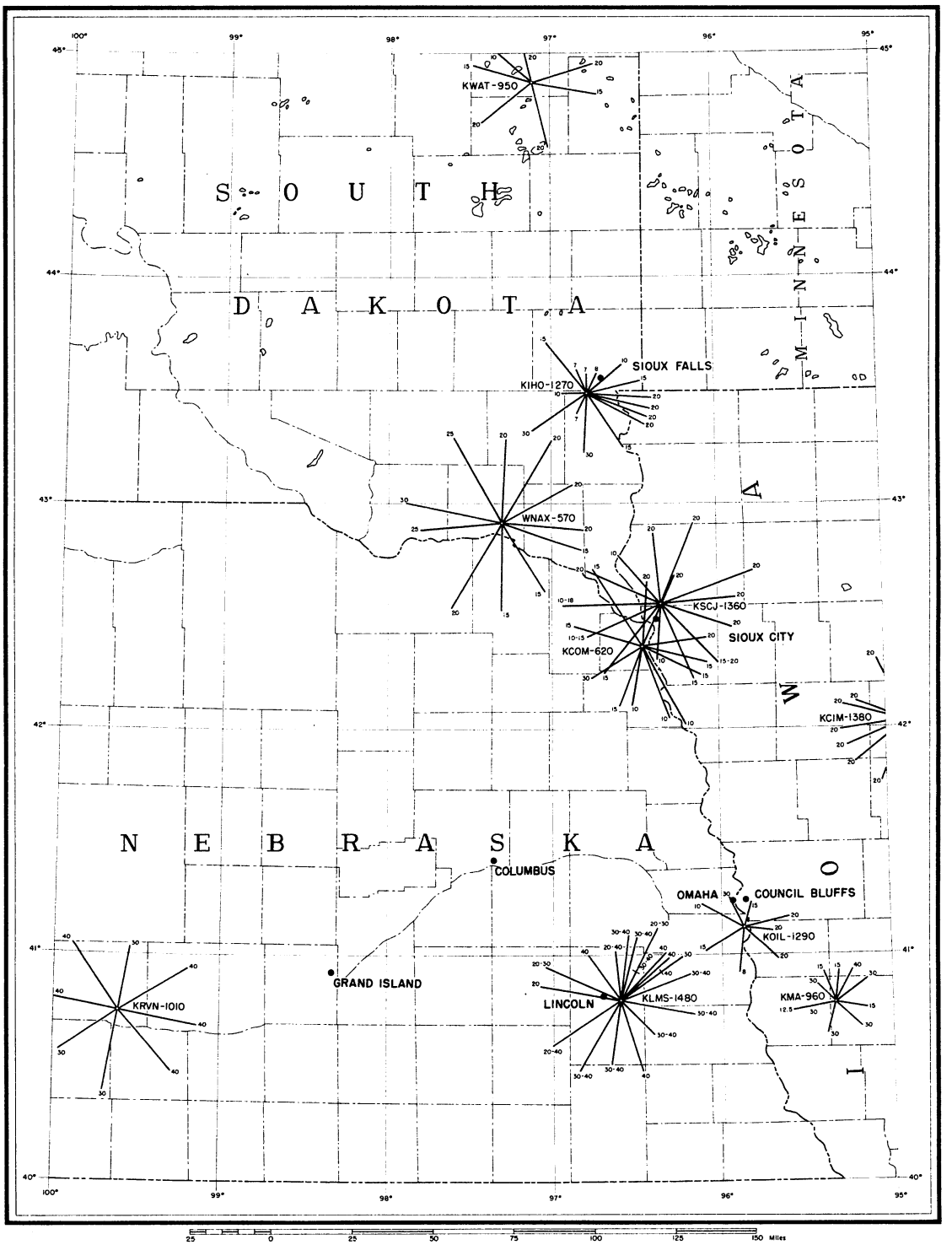


MAP 15.

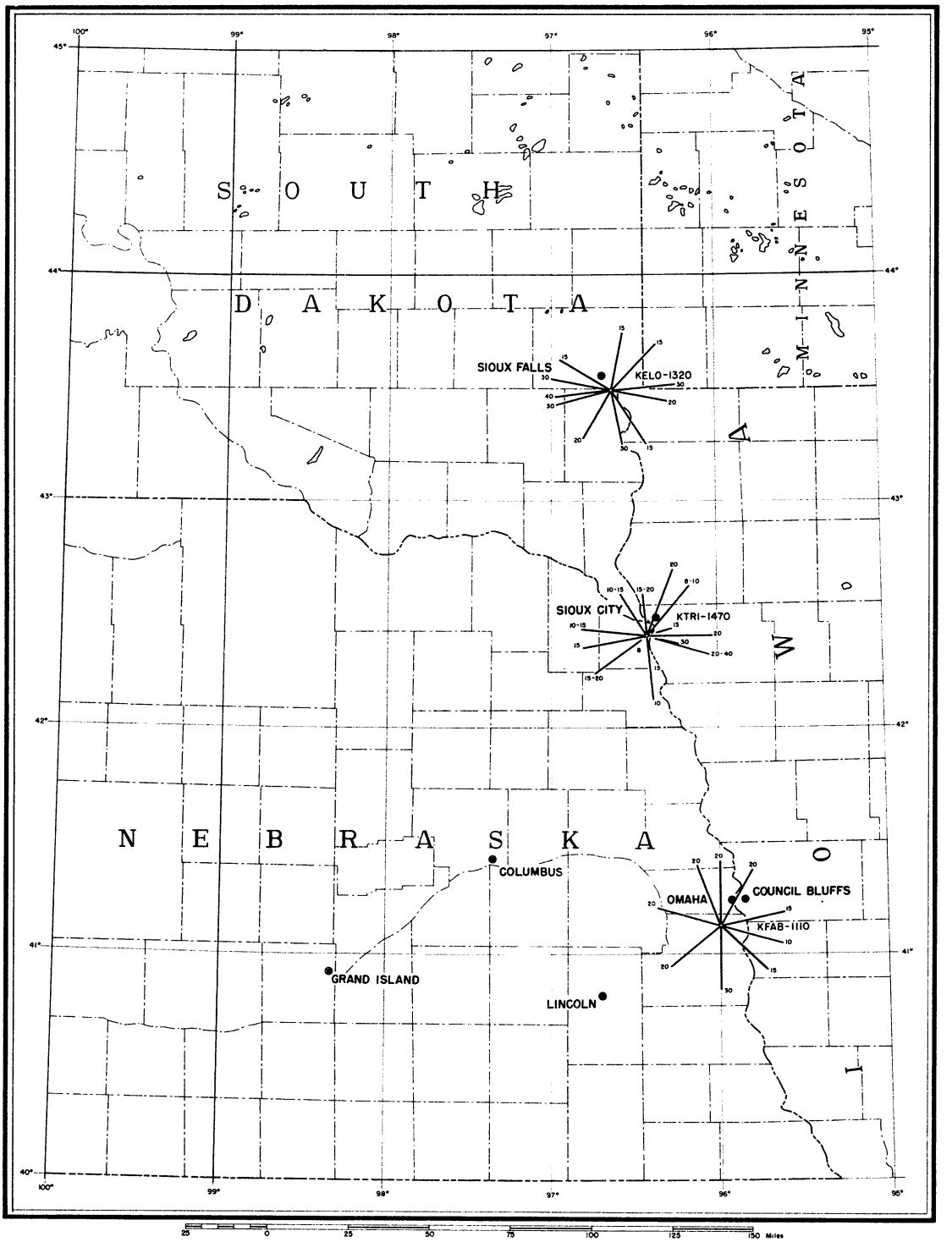
282270 O - 54 - 4



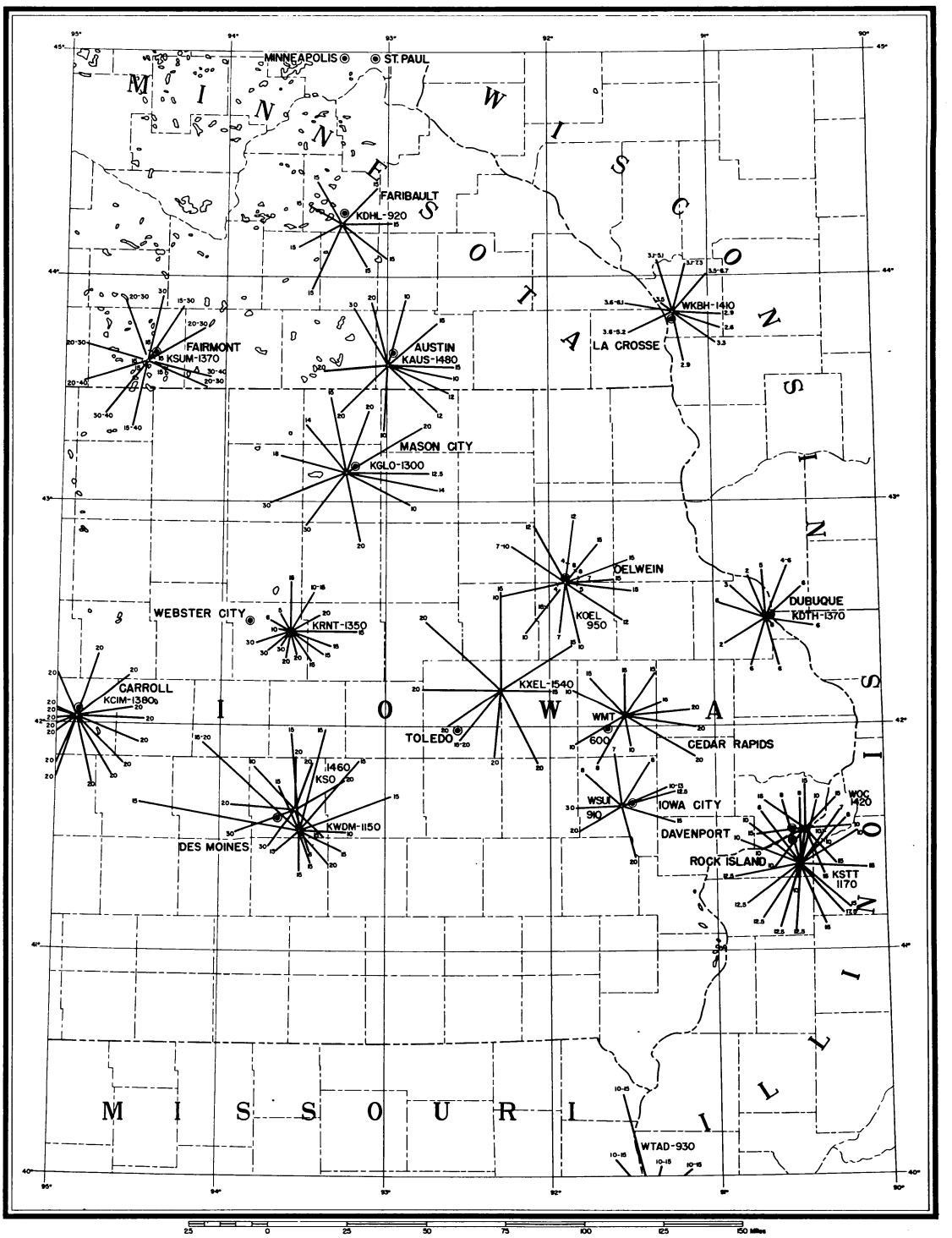
MAP 16.



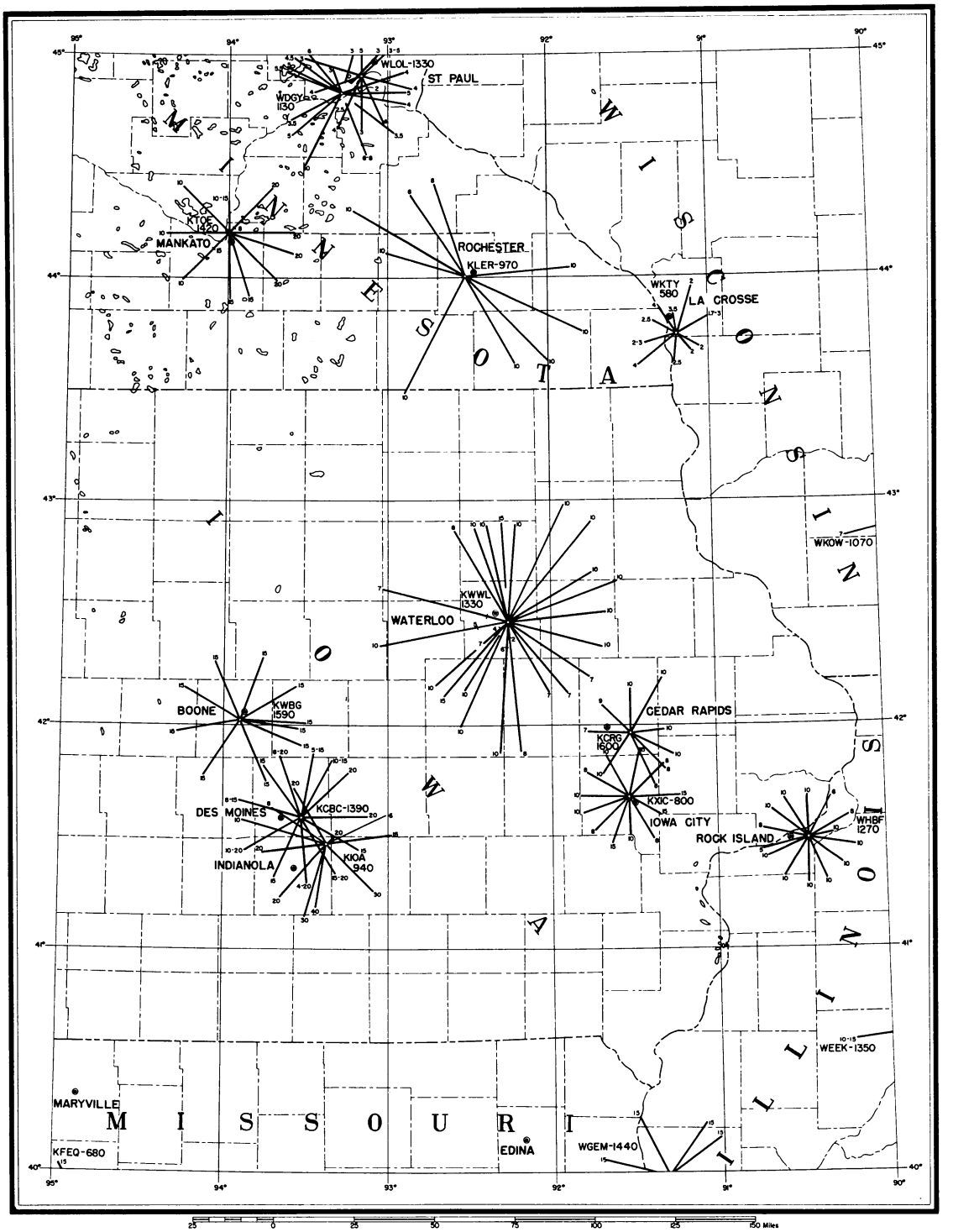
MAP 17a.



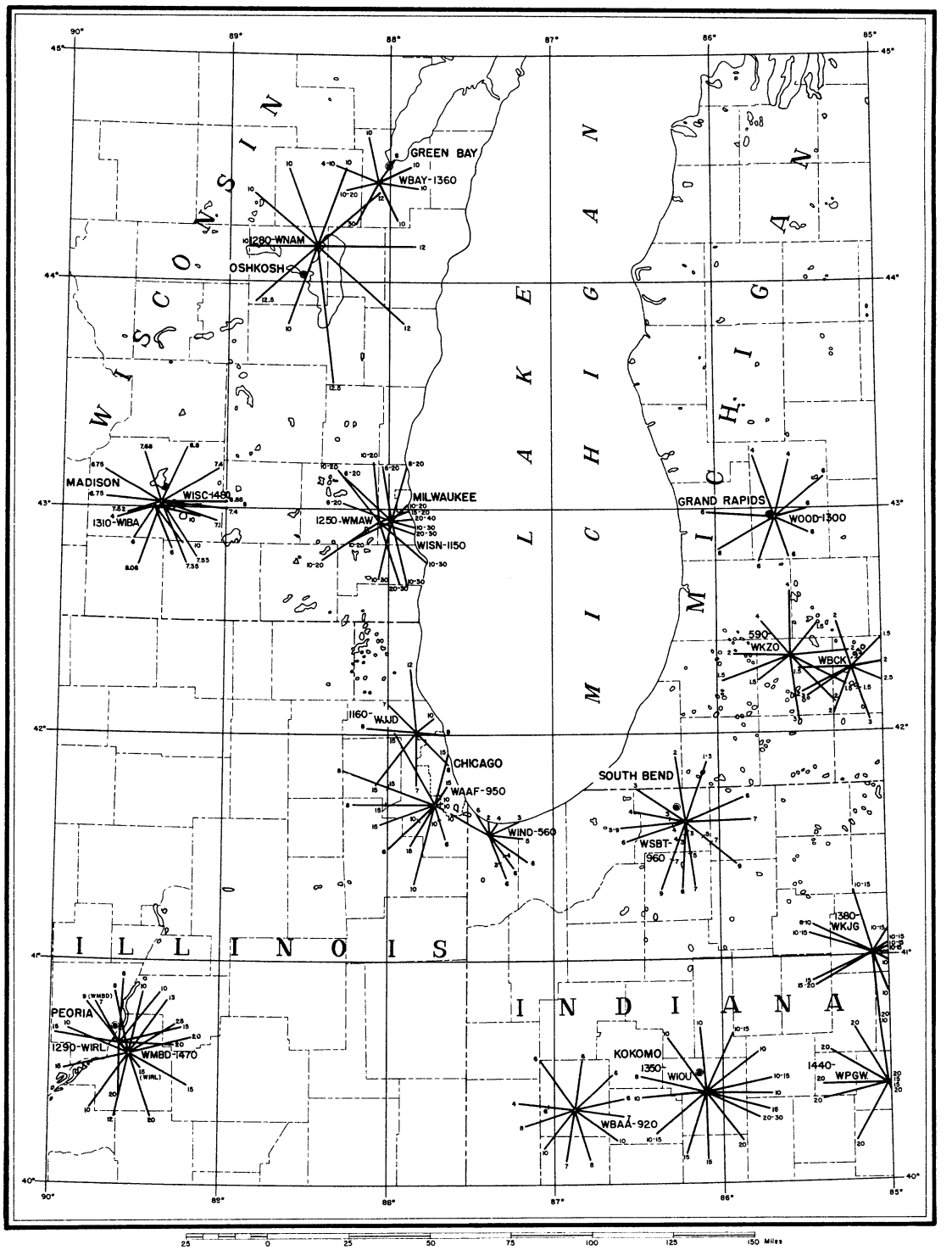
MAP 17b.



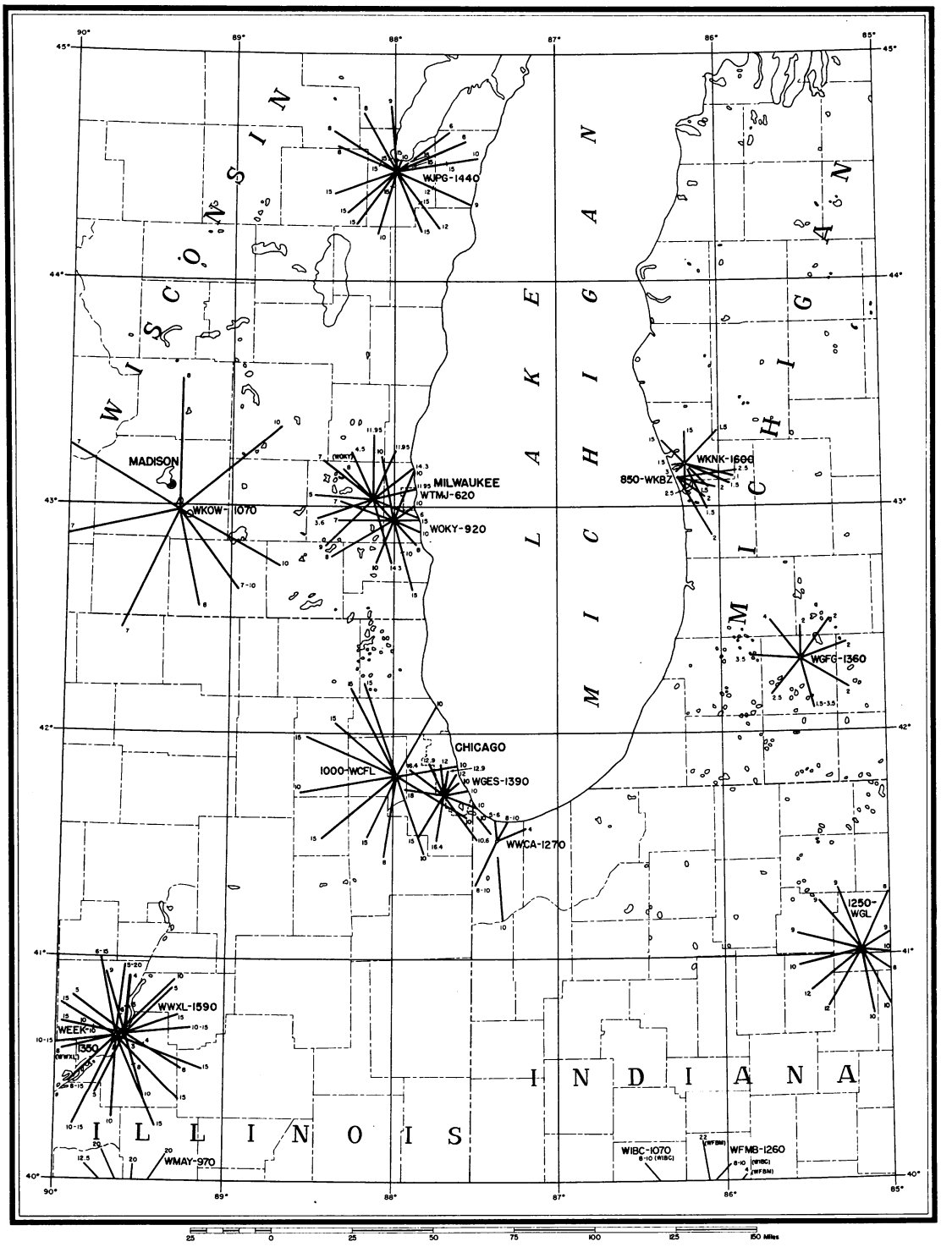
MAP 18a.



MAP 18b.

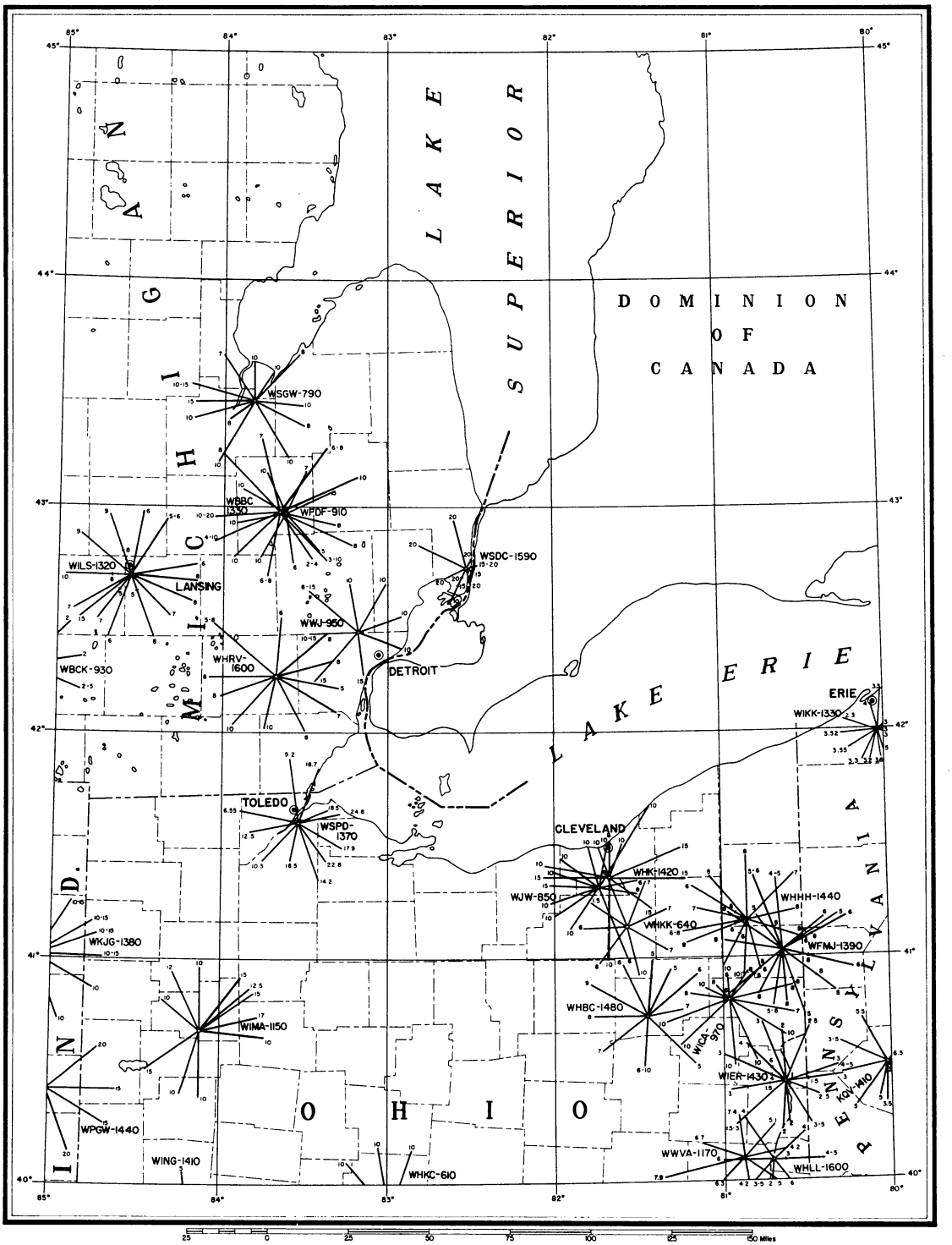


MAP 19a.

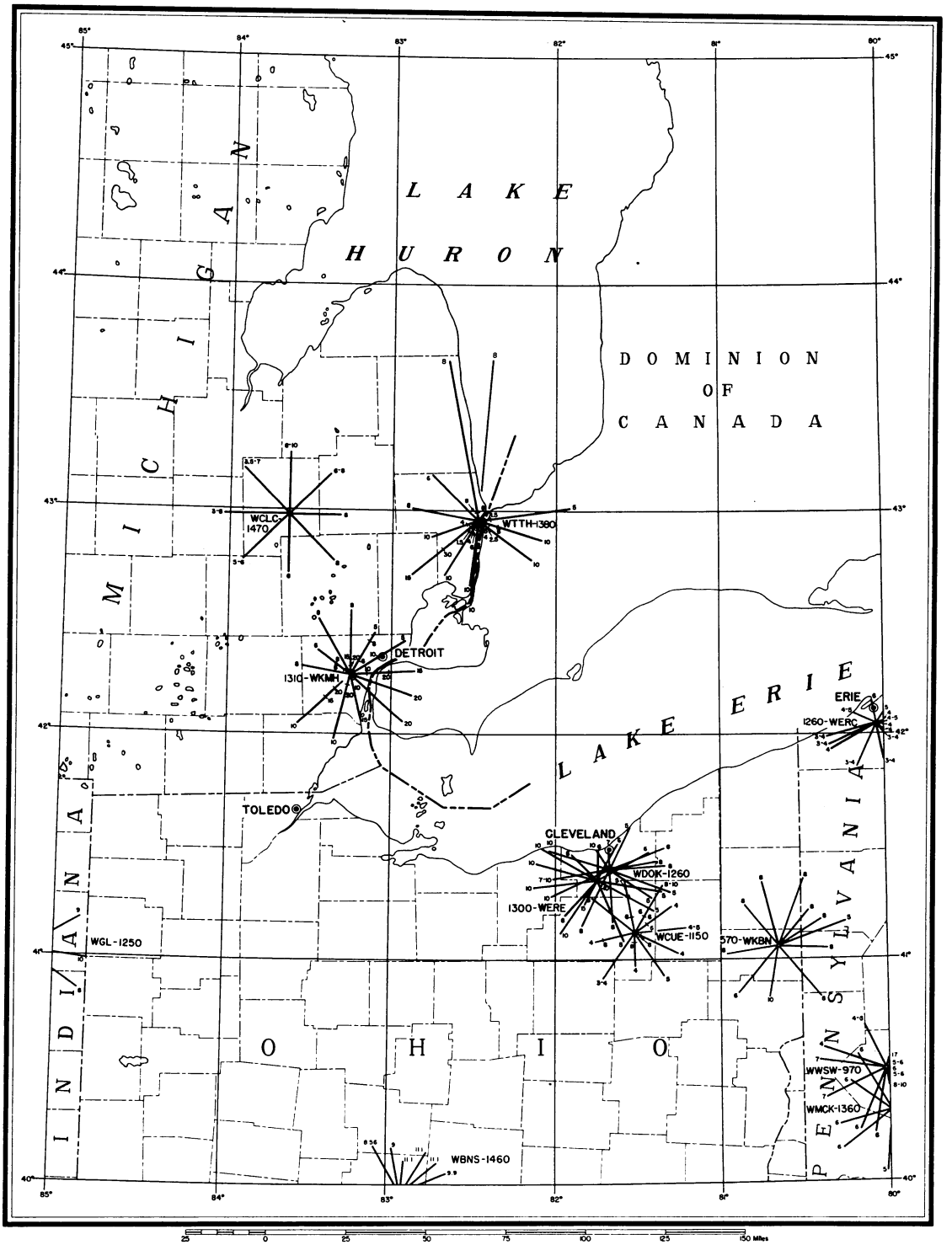


MAP 19b.

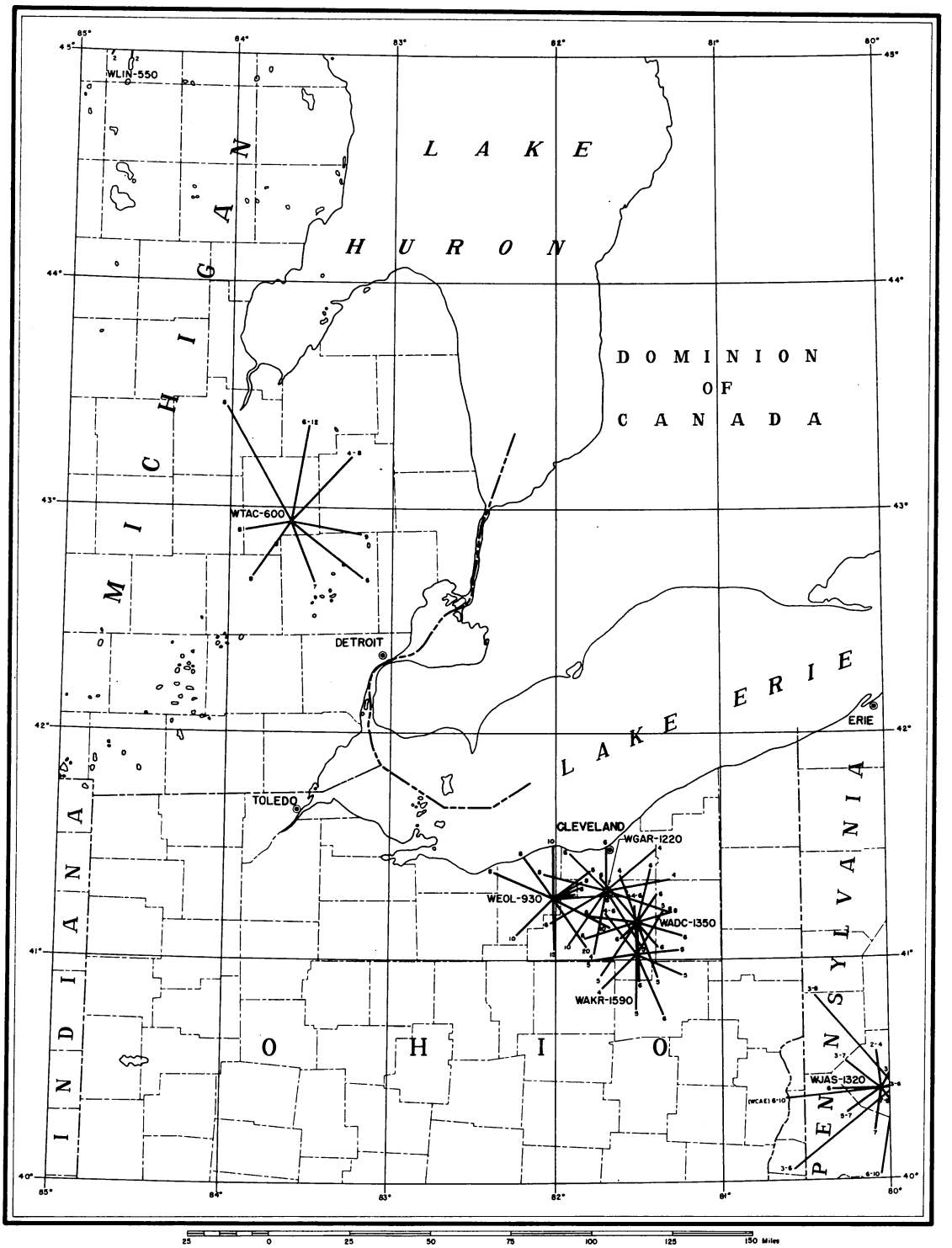
282270 O - 54 - 5



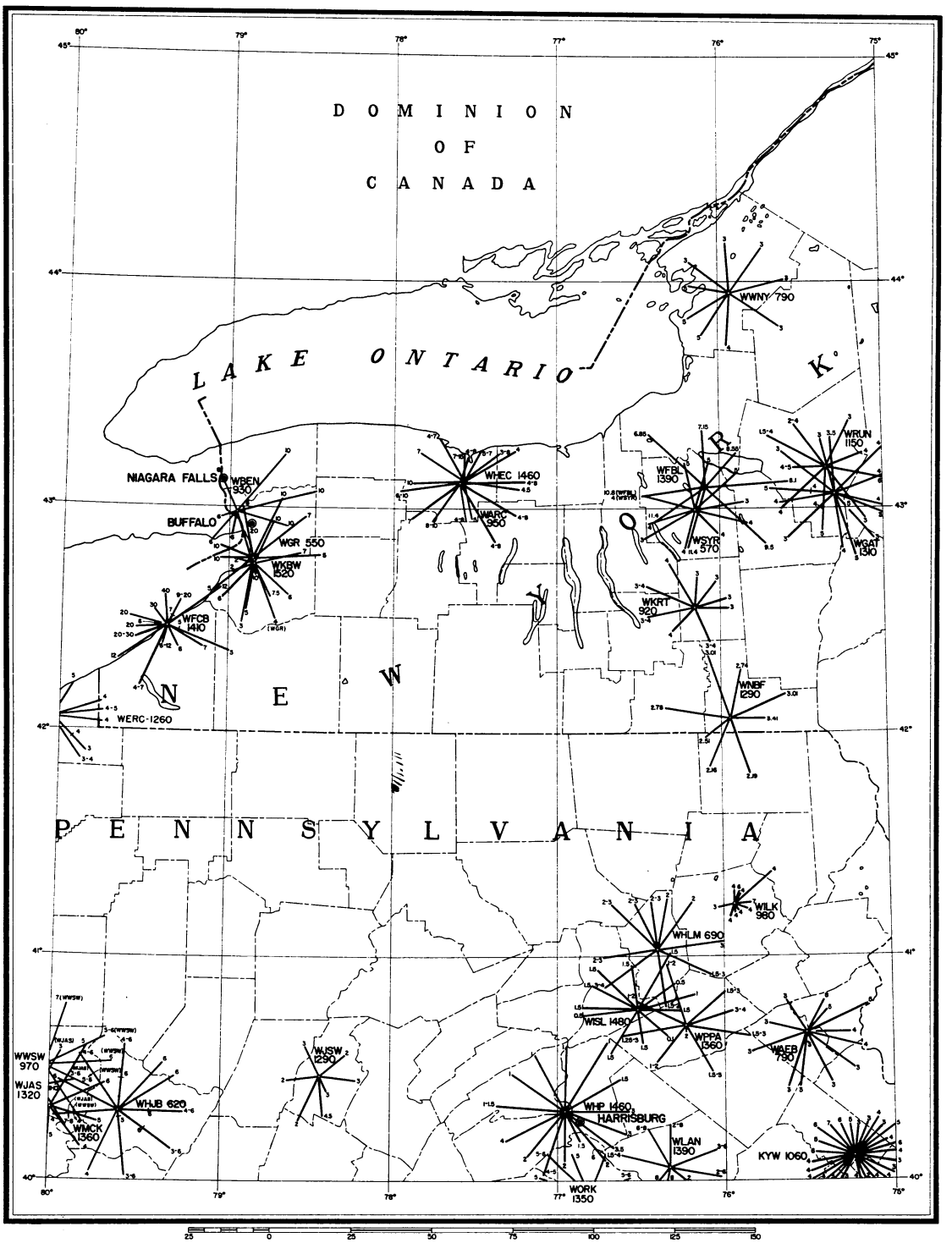
MAP 20a.



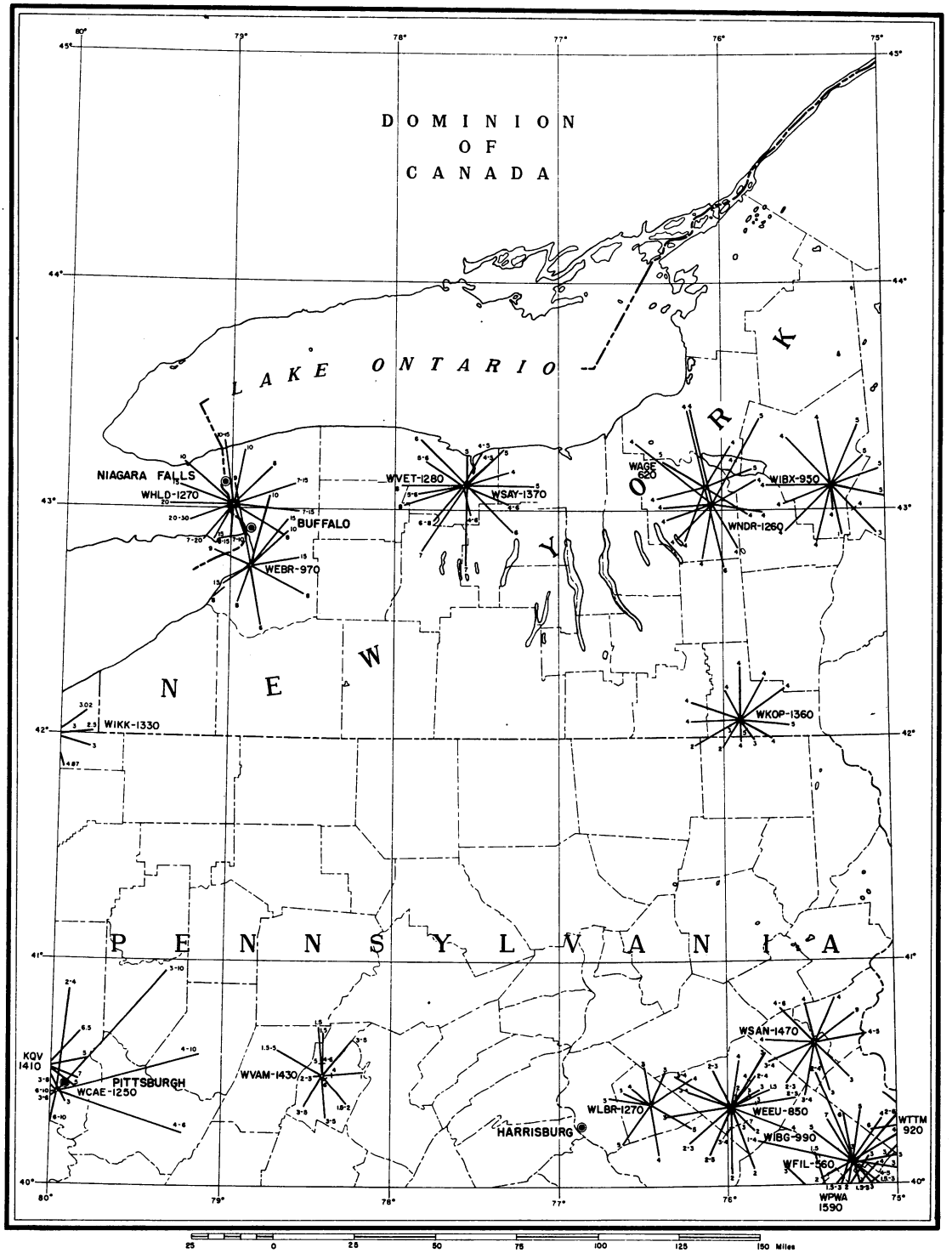
MAP 20b.



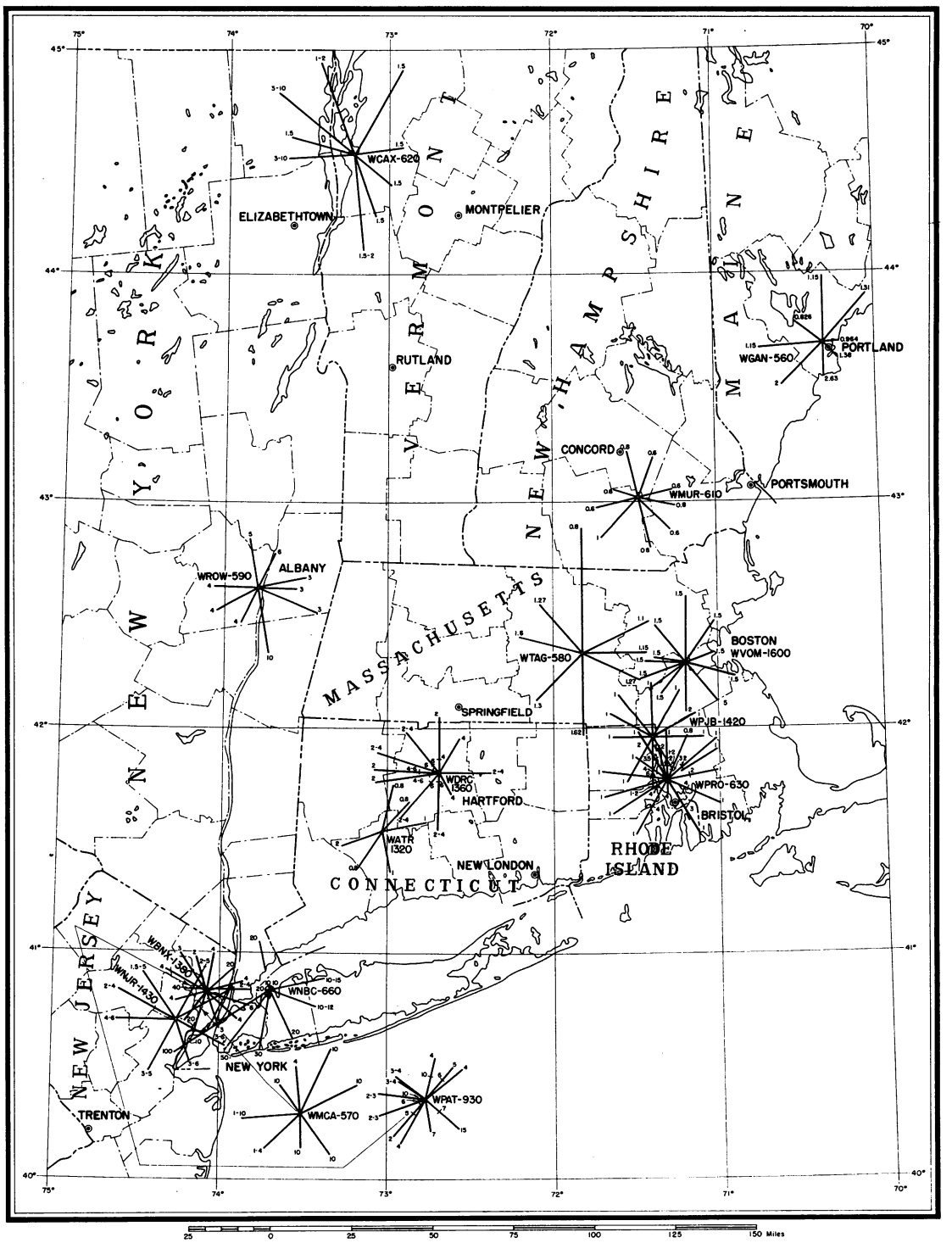
MAP 20c.



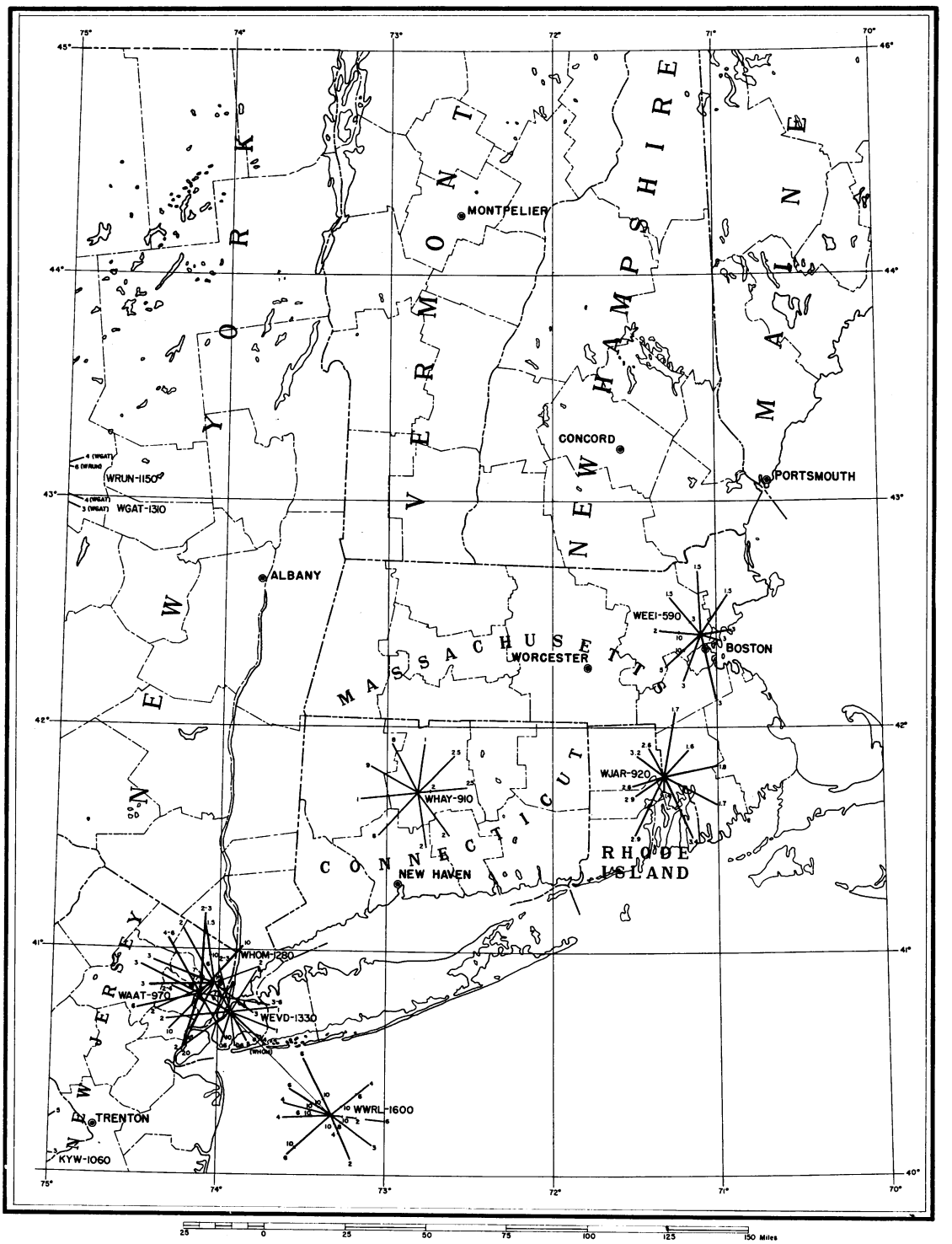
MAP 21a.



MAP 21b.

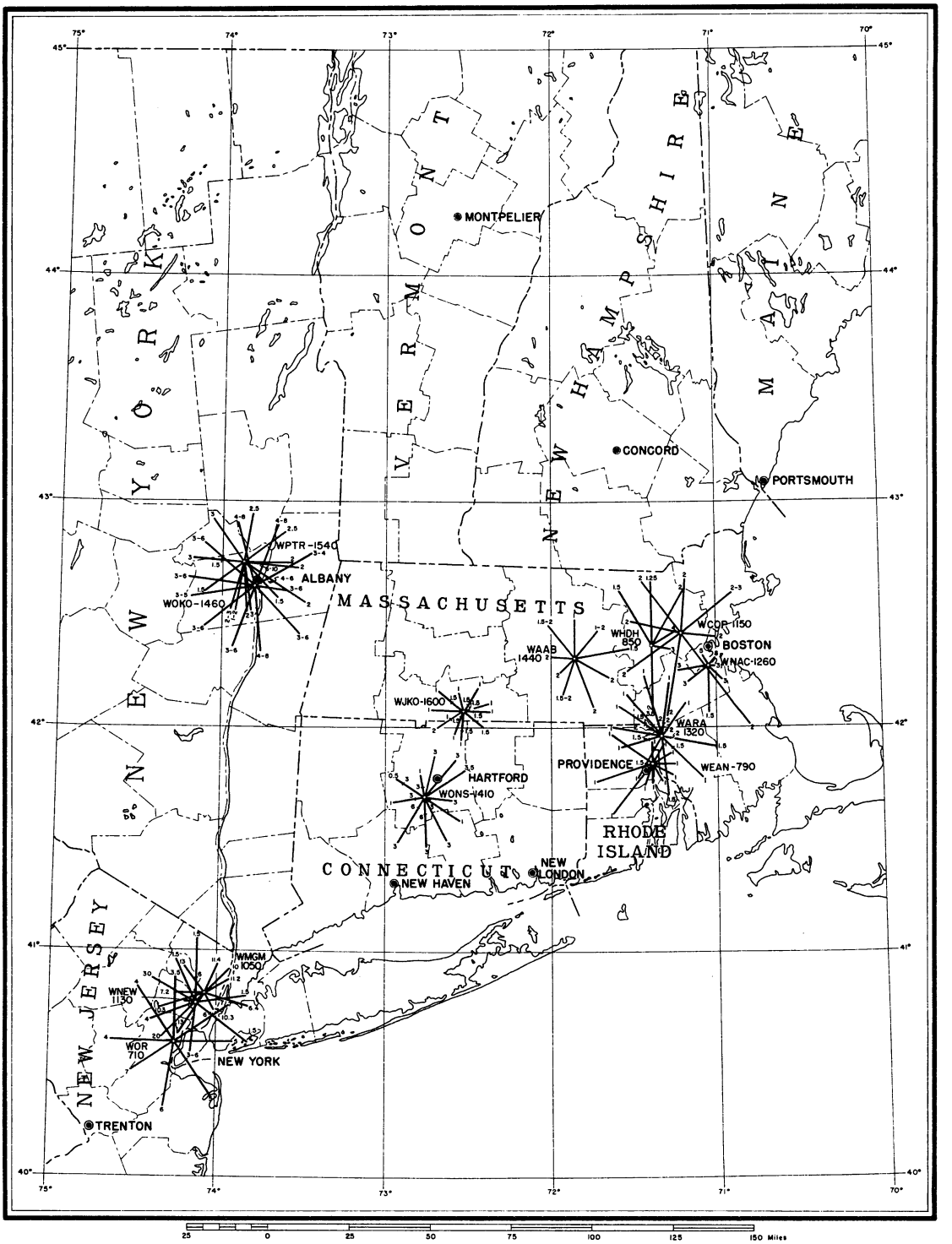


MAP 22a.

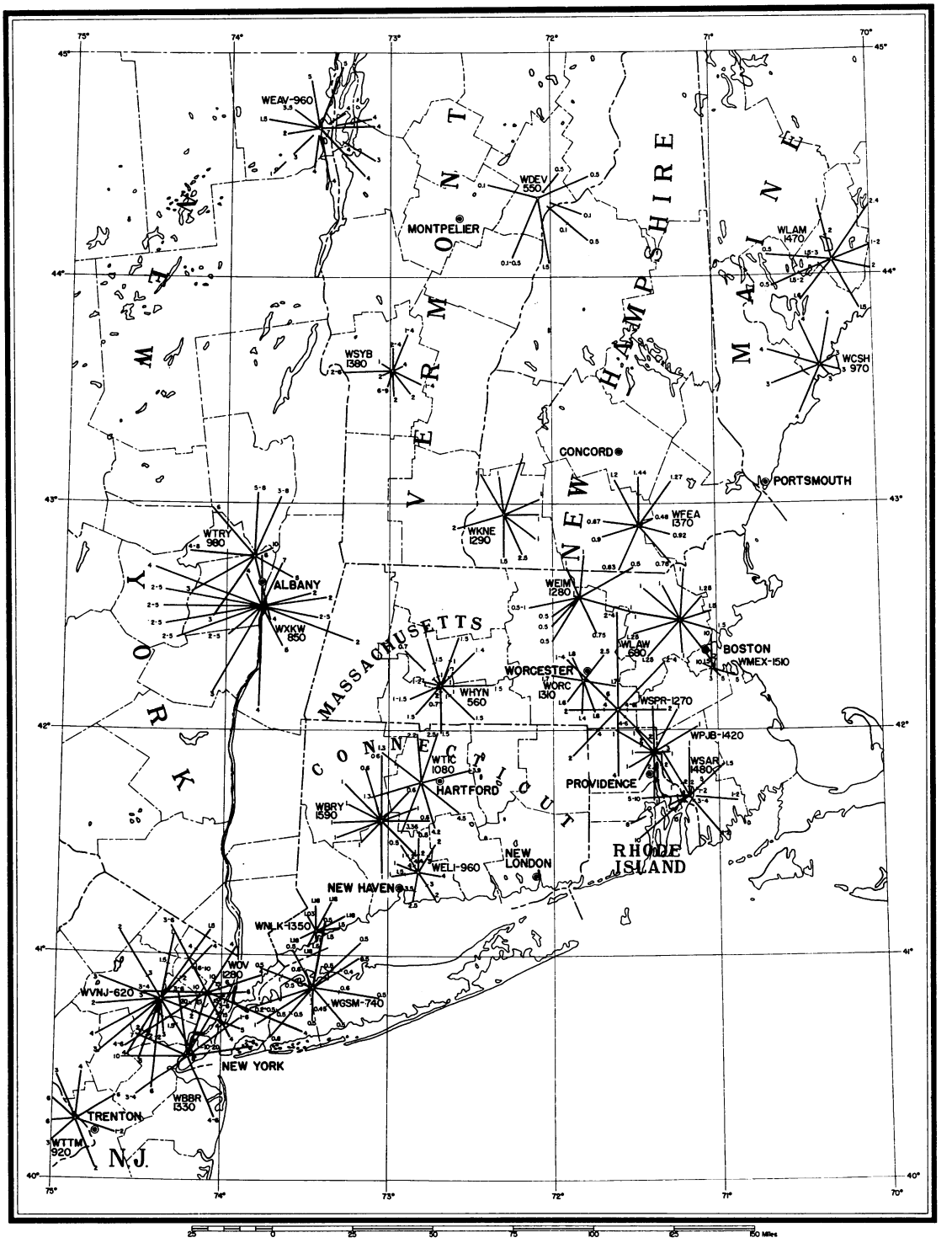


MAP 22b.

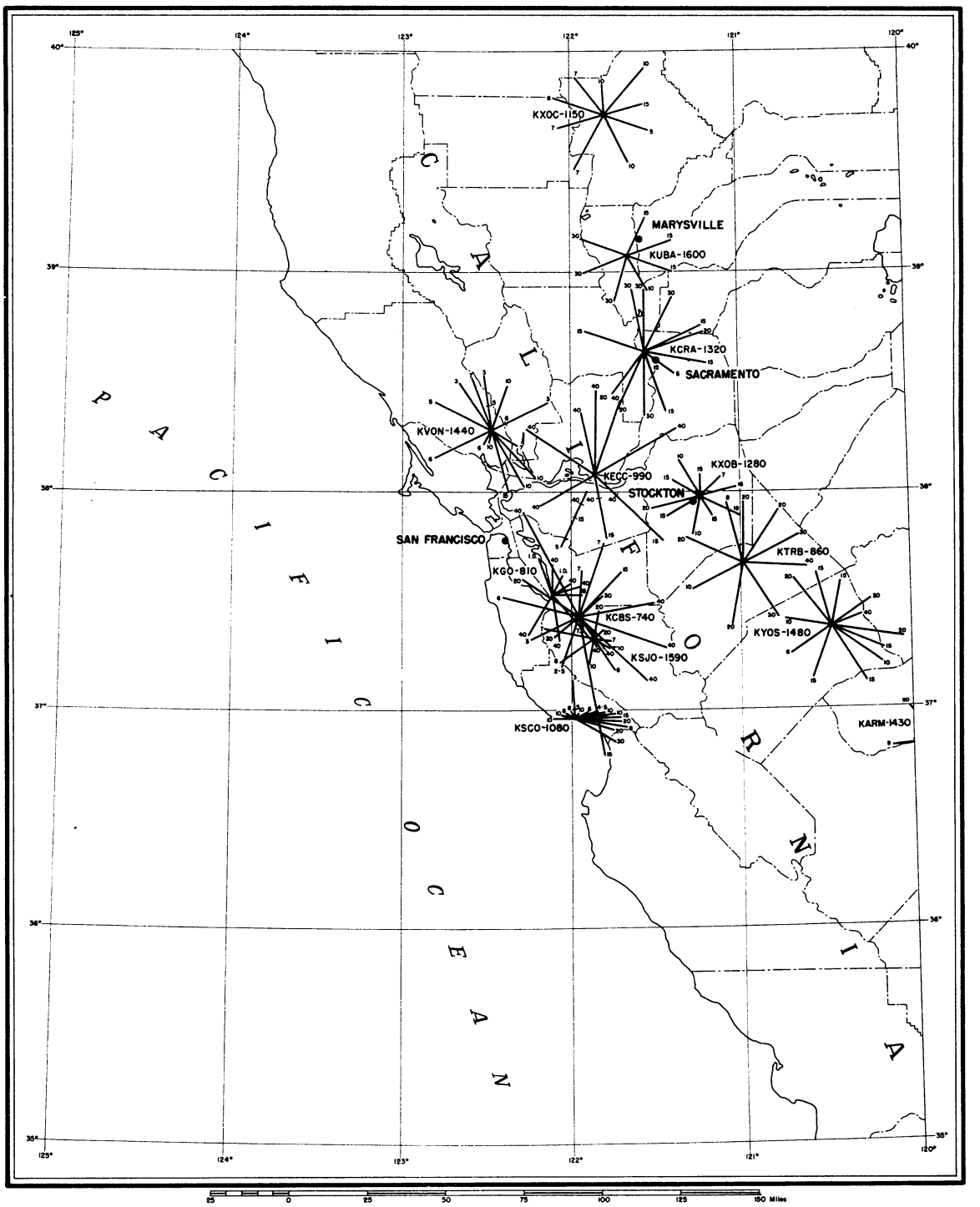
282270 O - 54 - 6



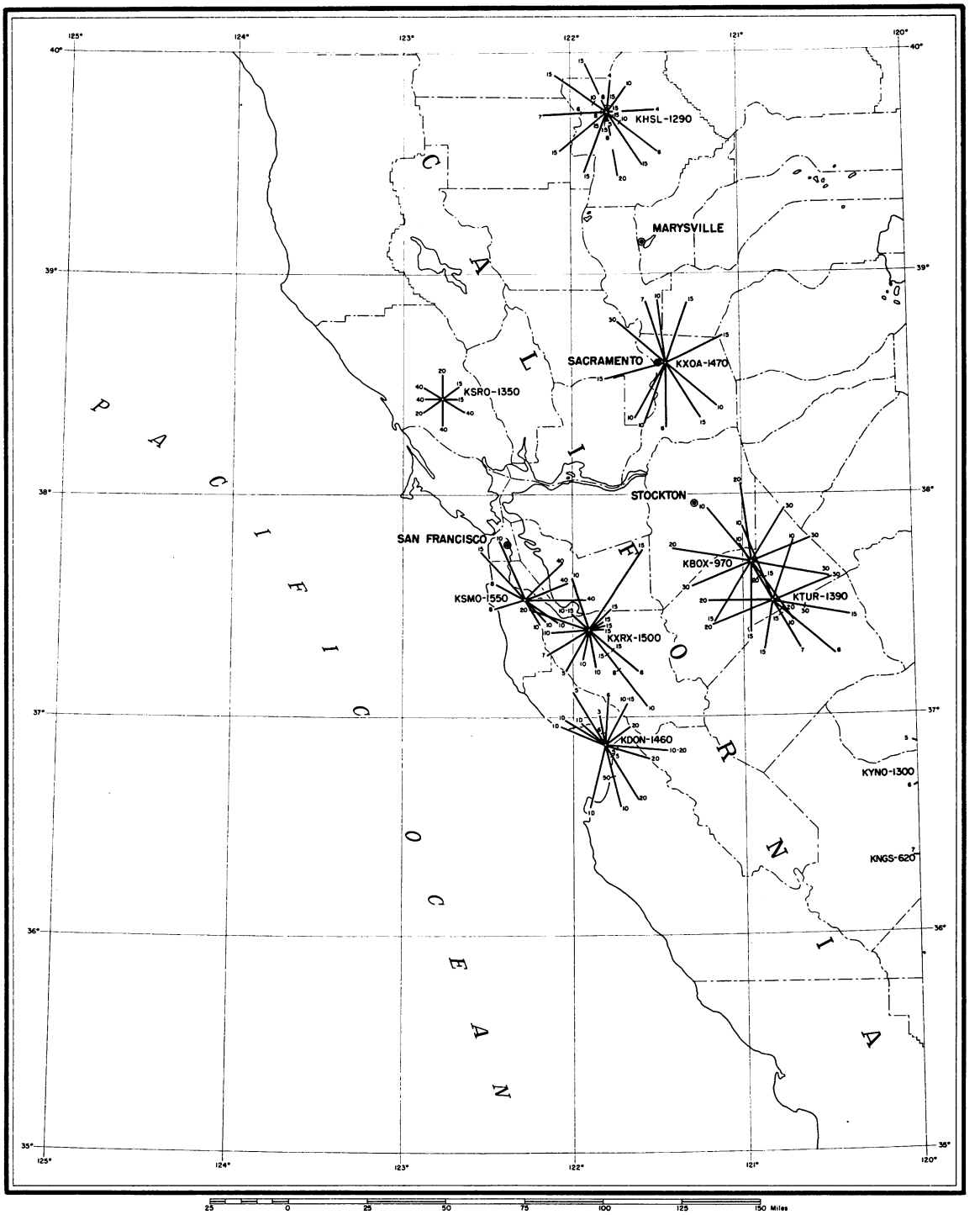
MAP 22c.



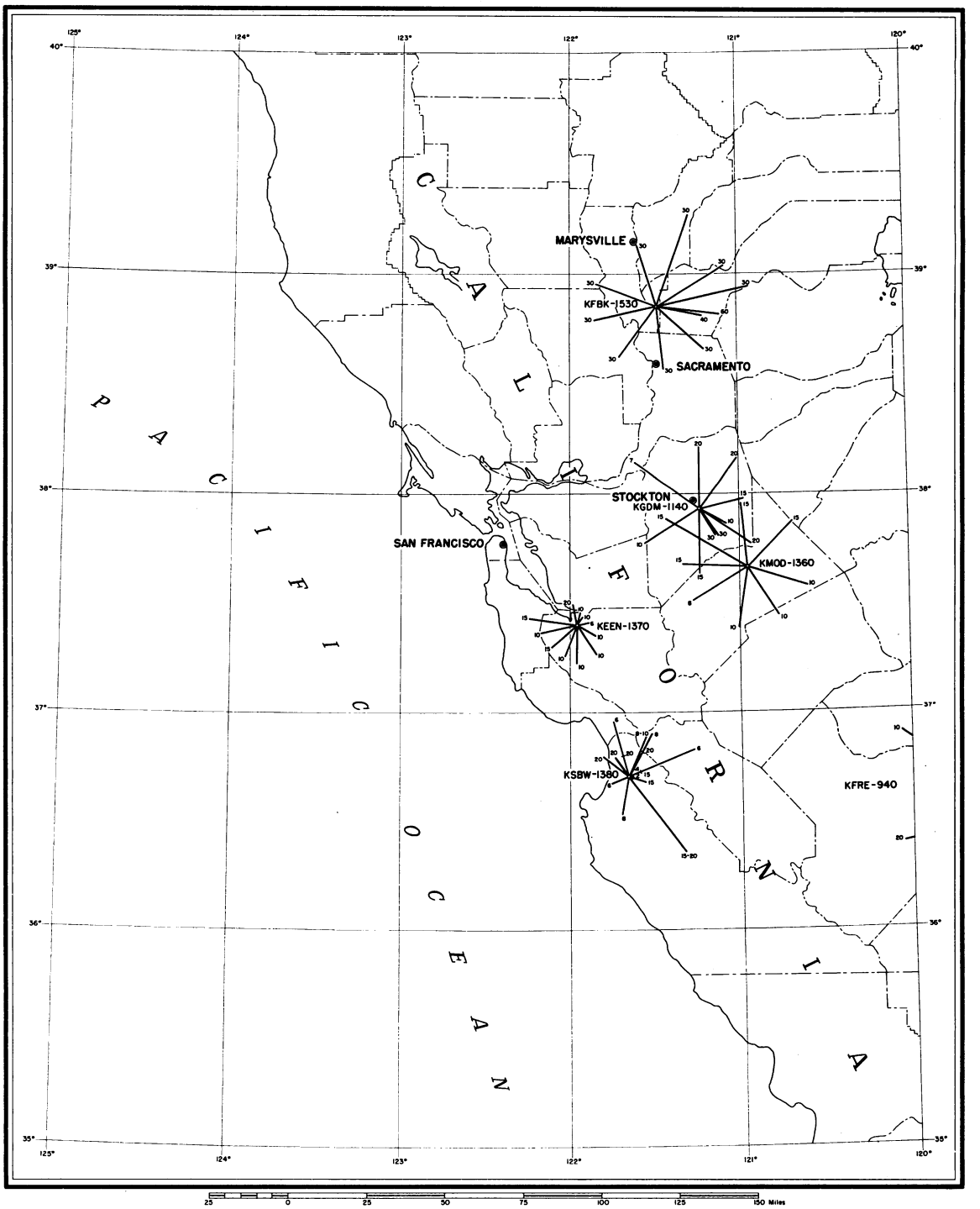
MAP 22d.



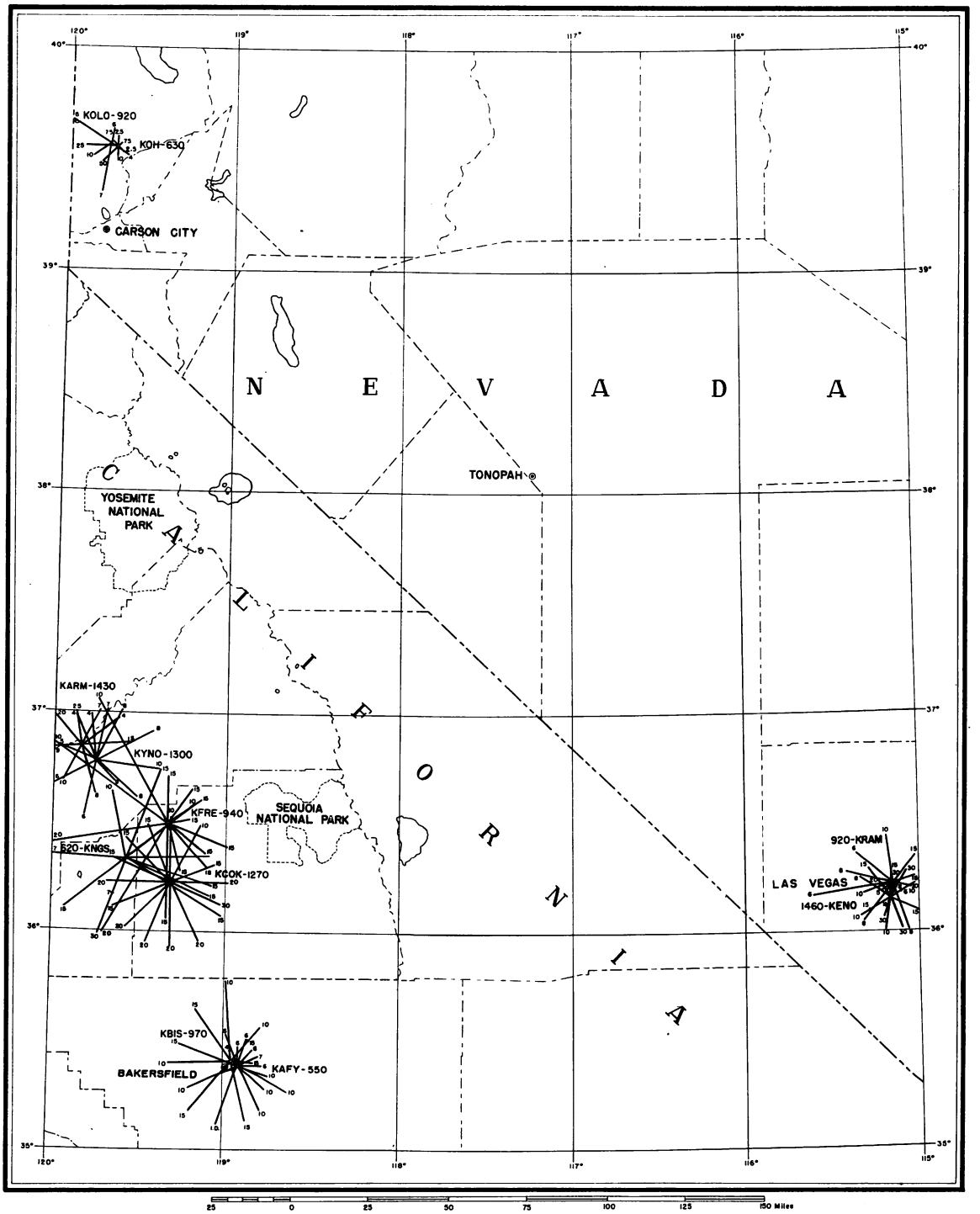
MAP 23a.



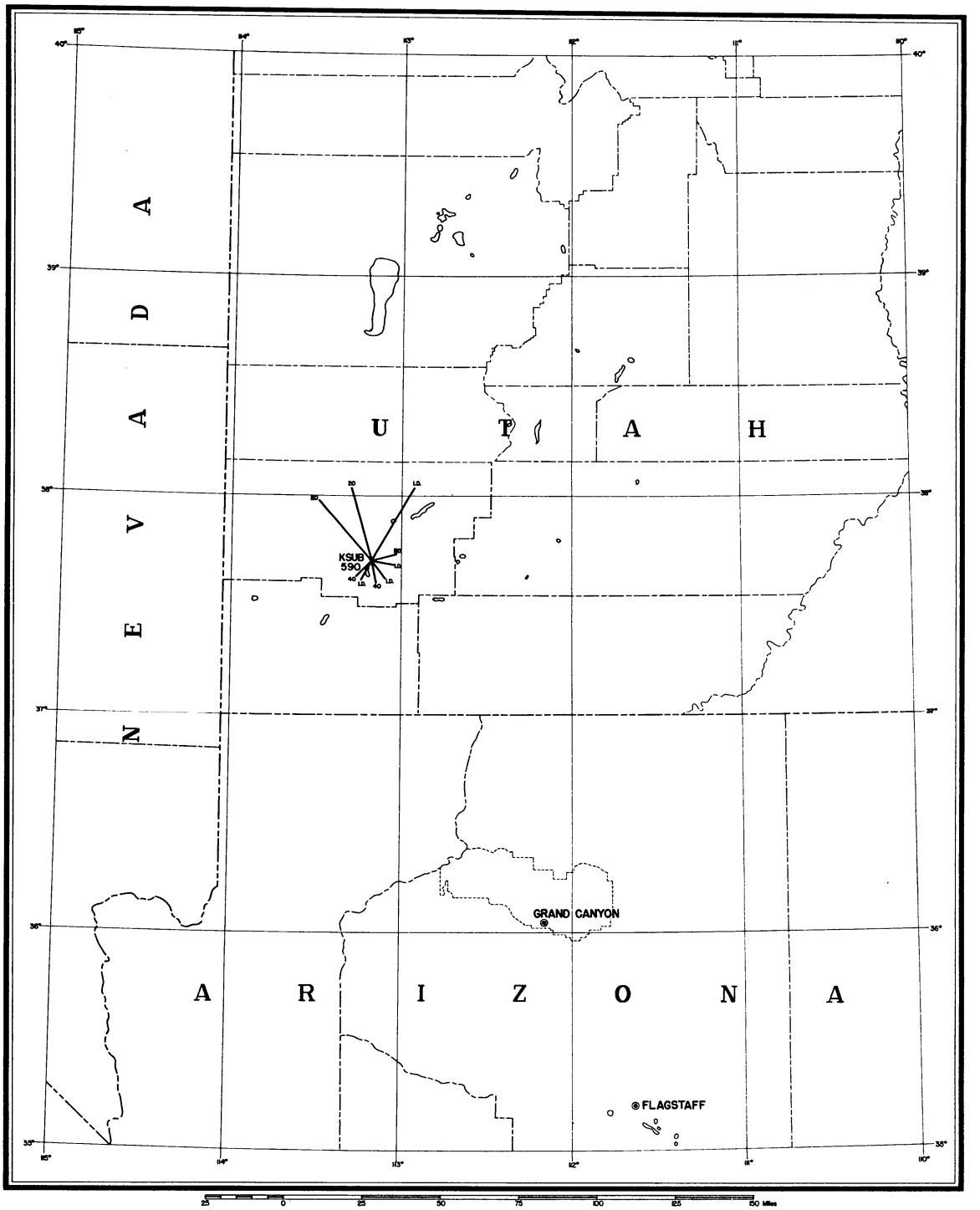
MAP 23b.



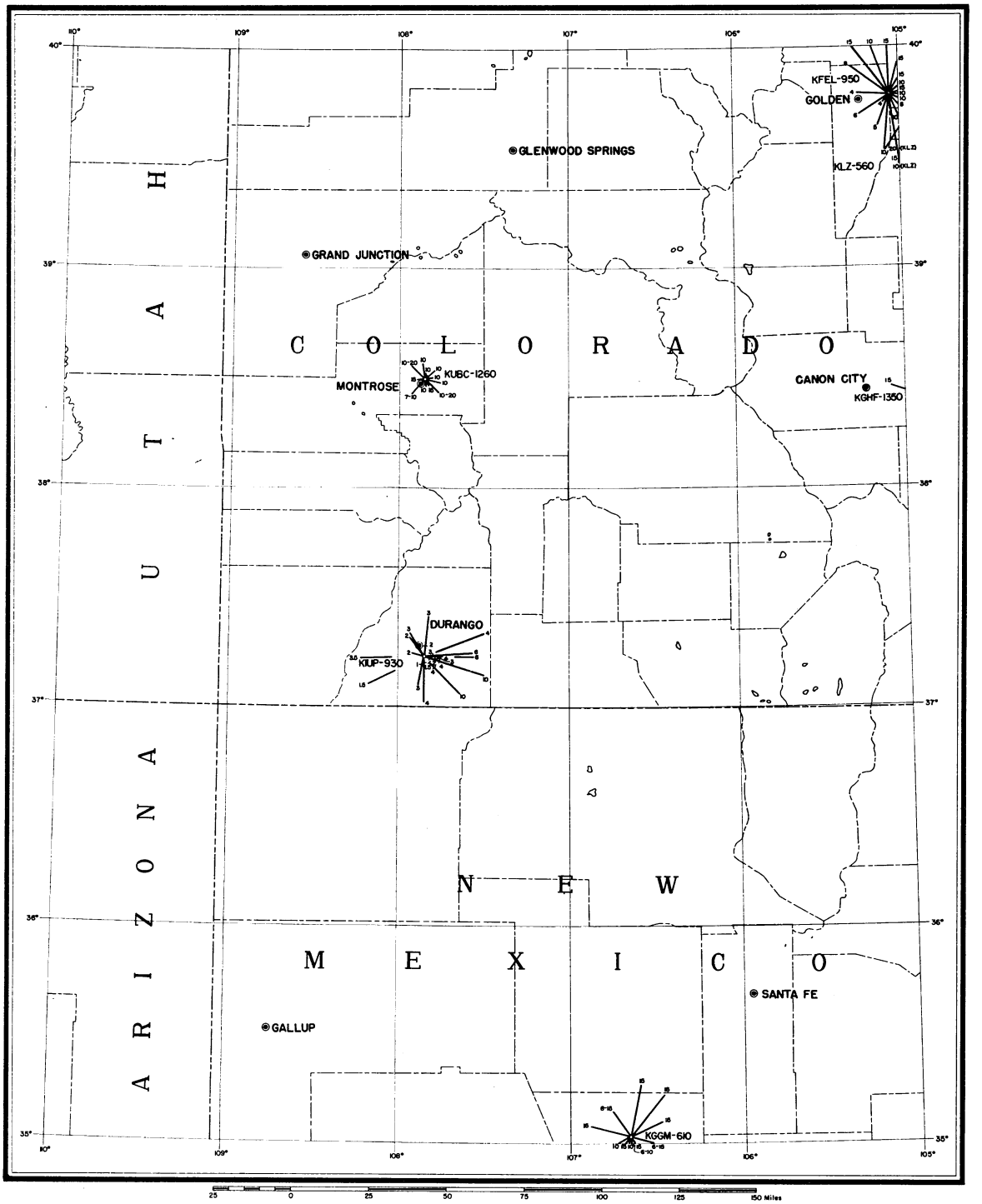
MAP 23c.



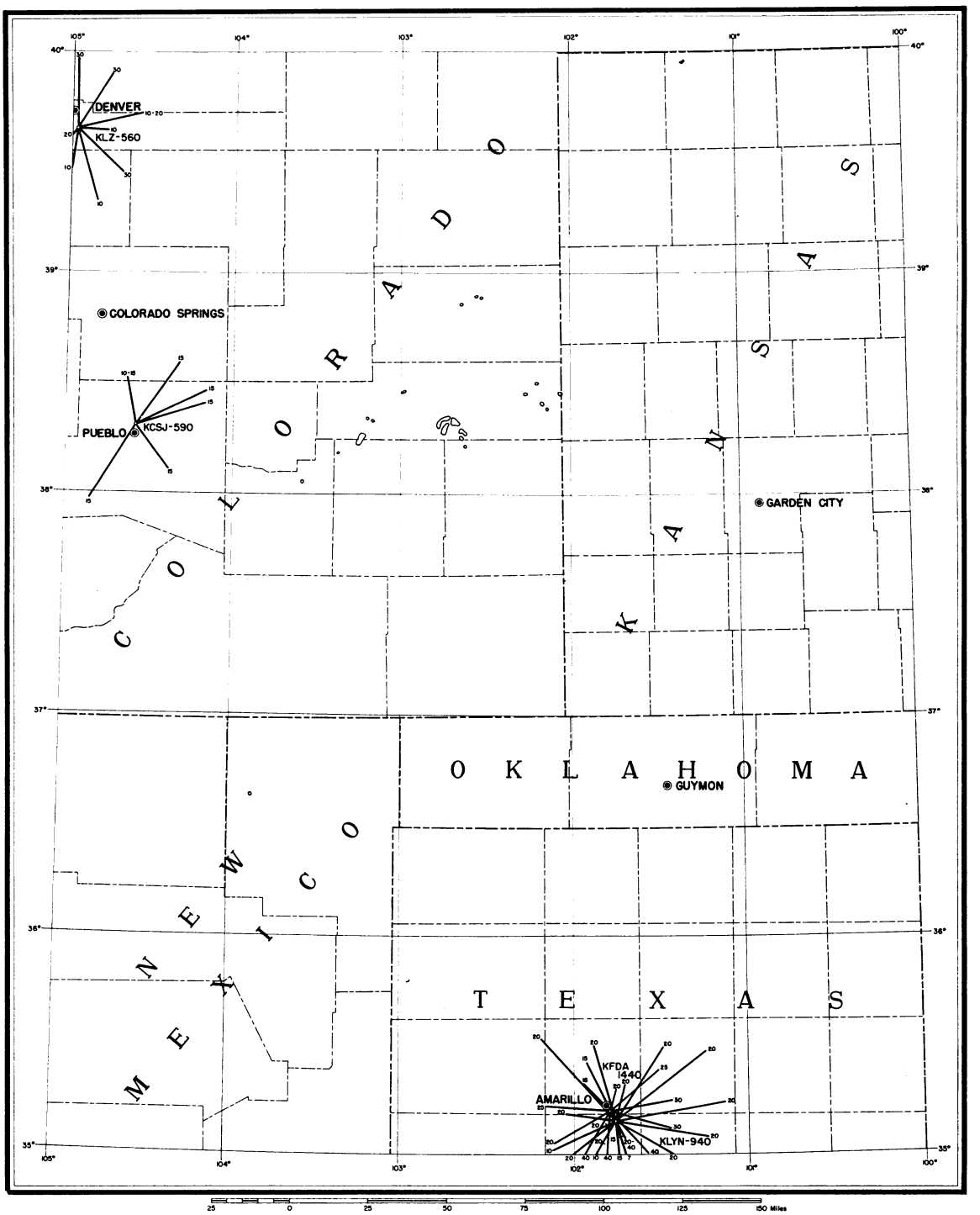
MAP 24.



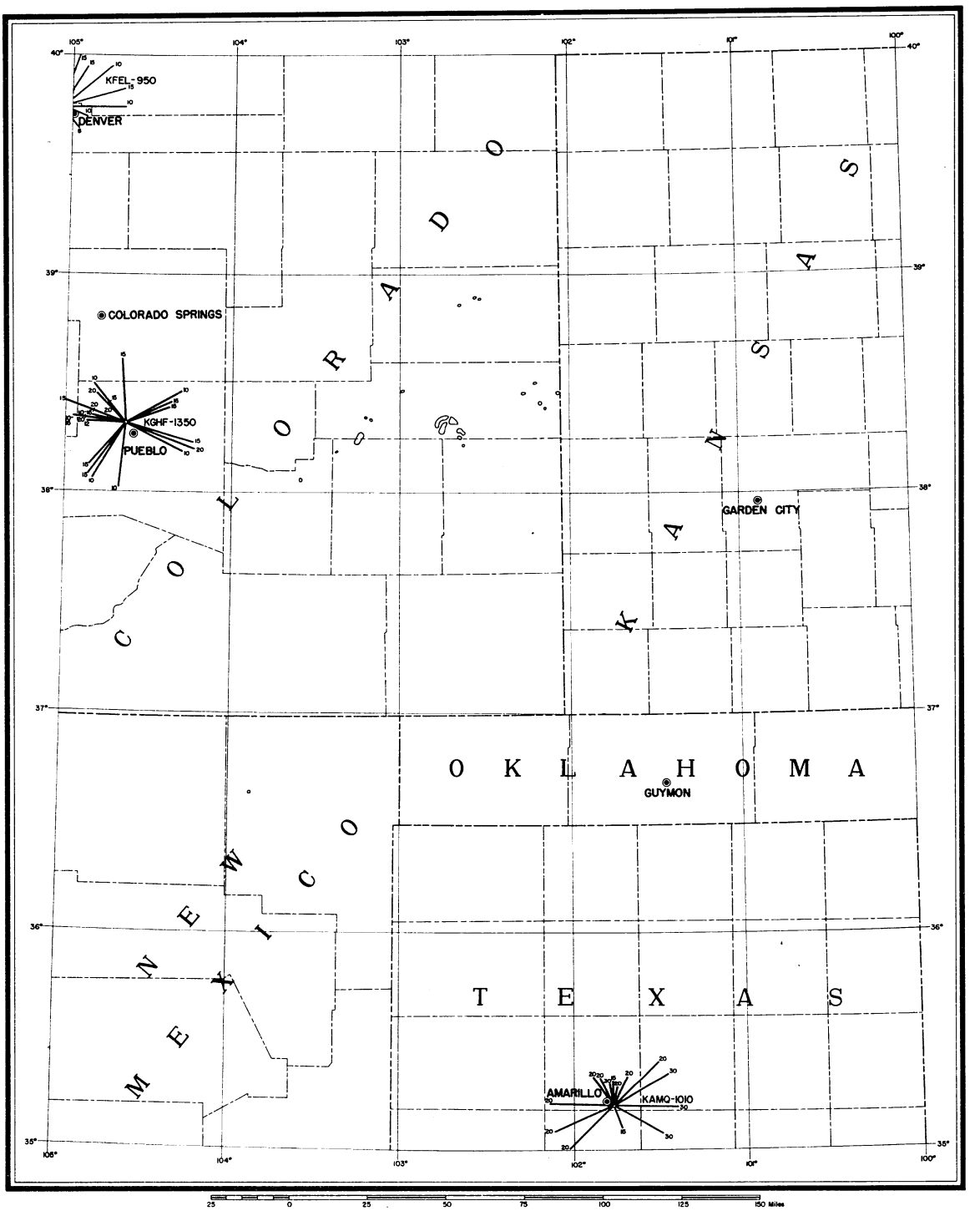
MAP 25.



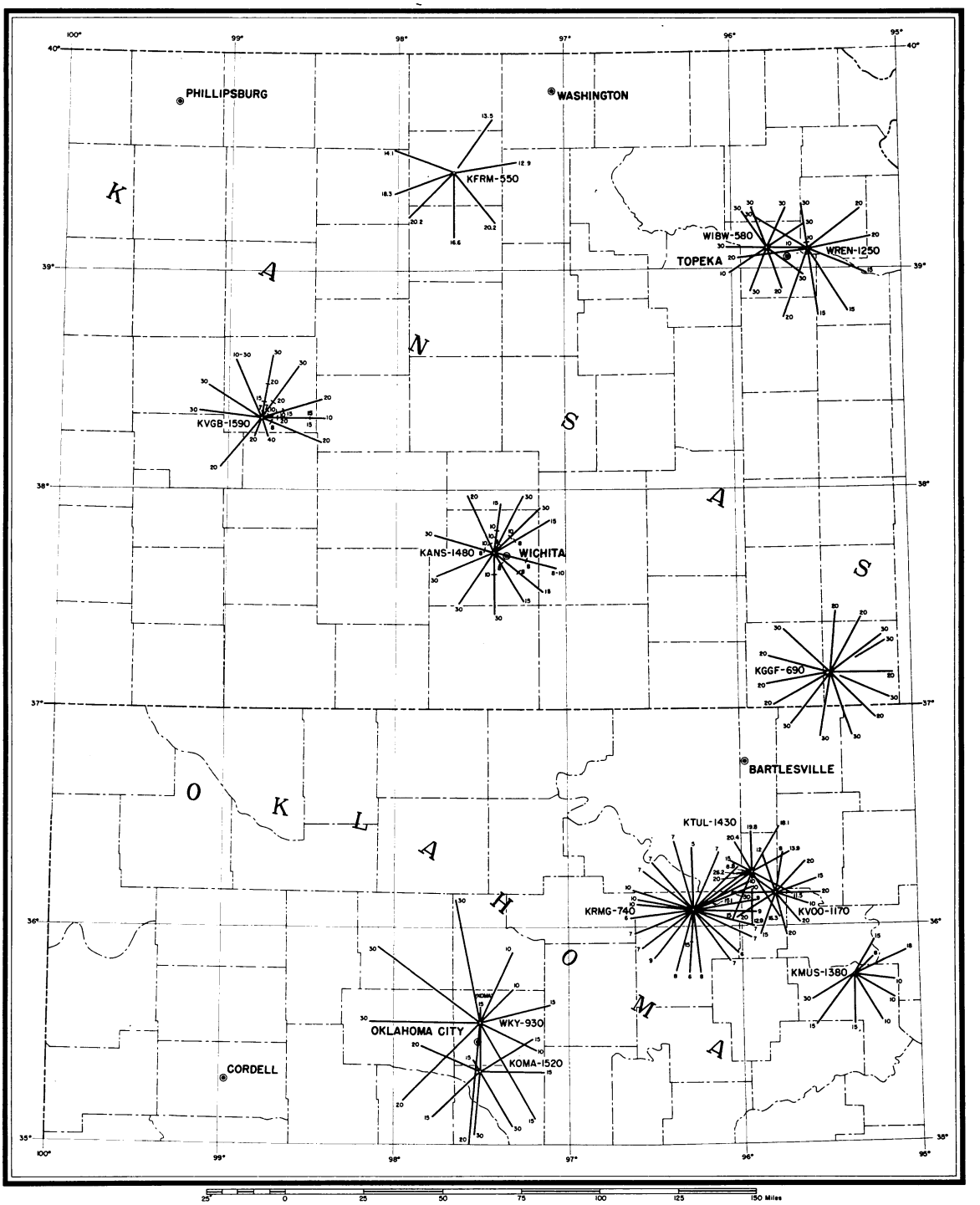
MAP 26.



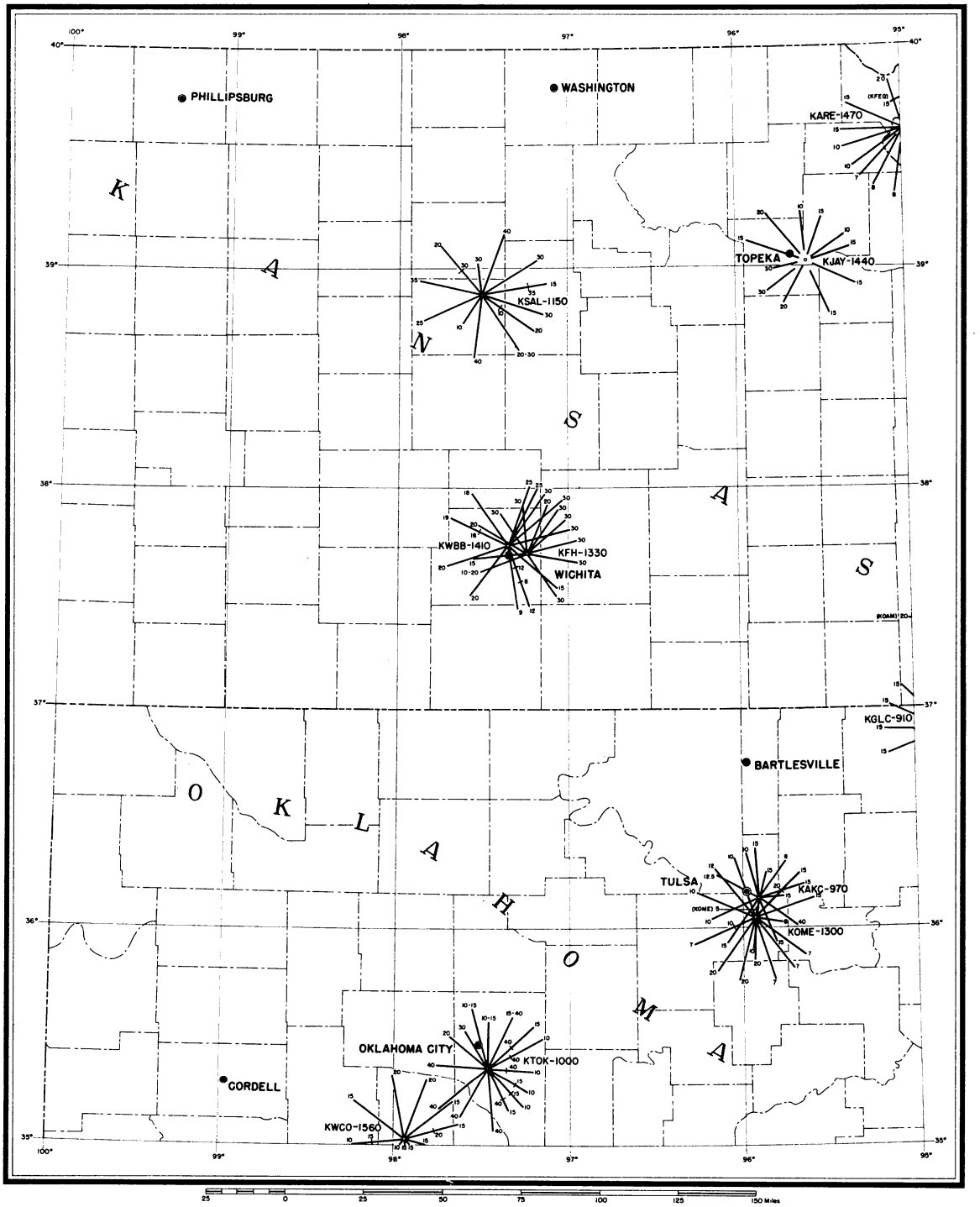
Map 27a.



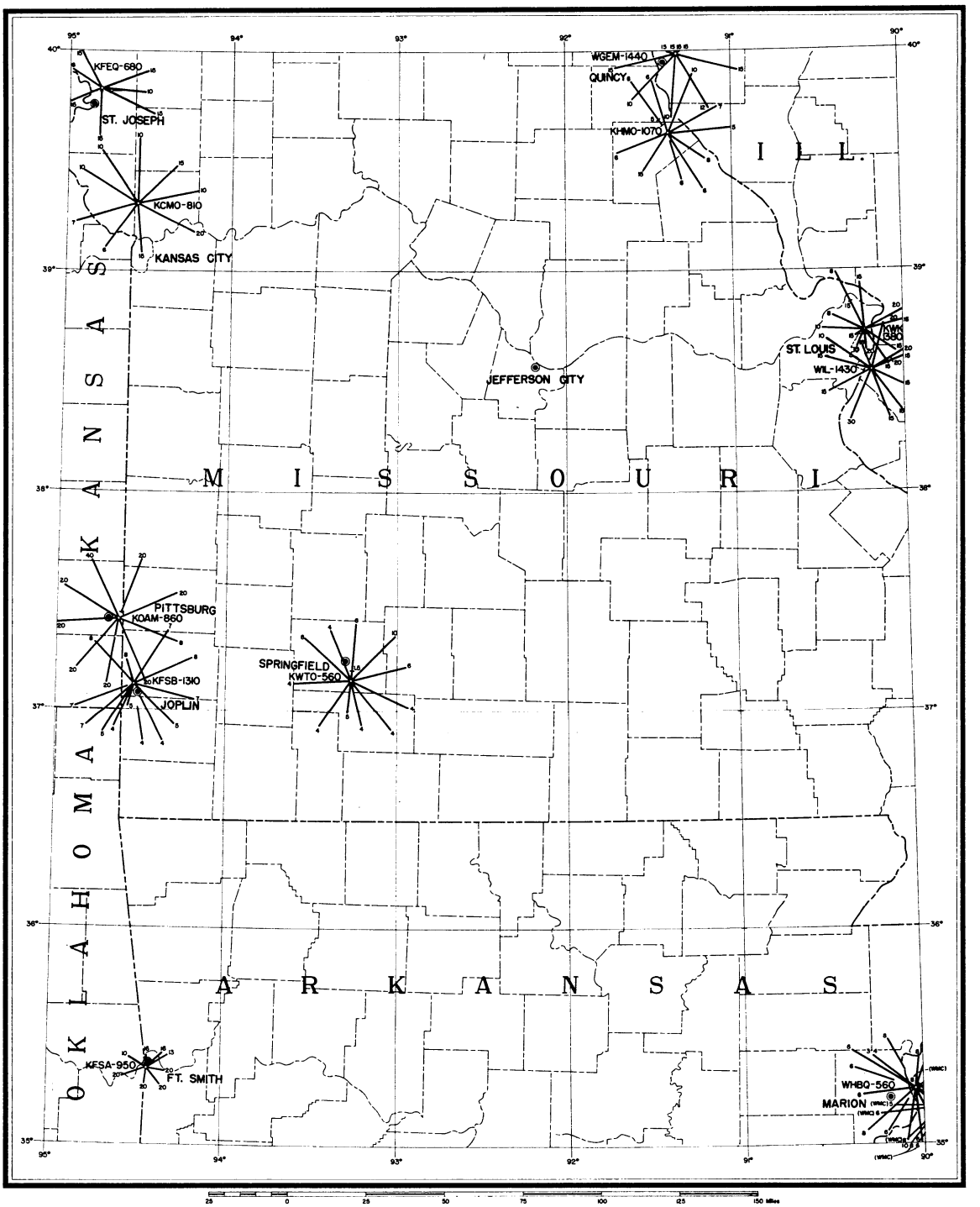
MAP 27b.



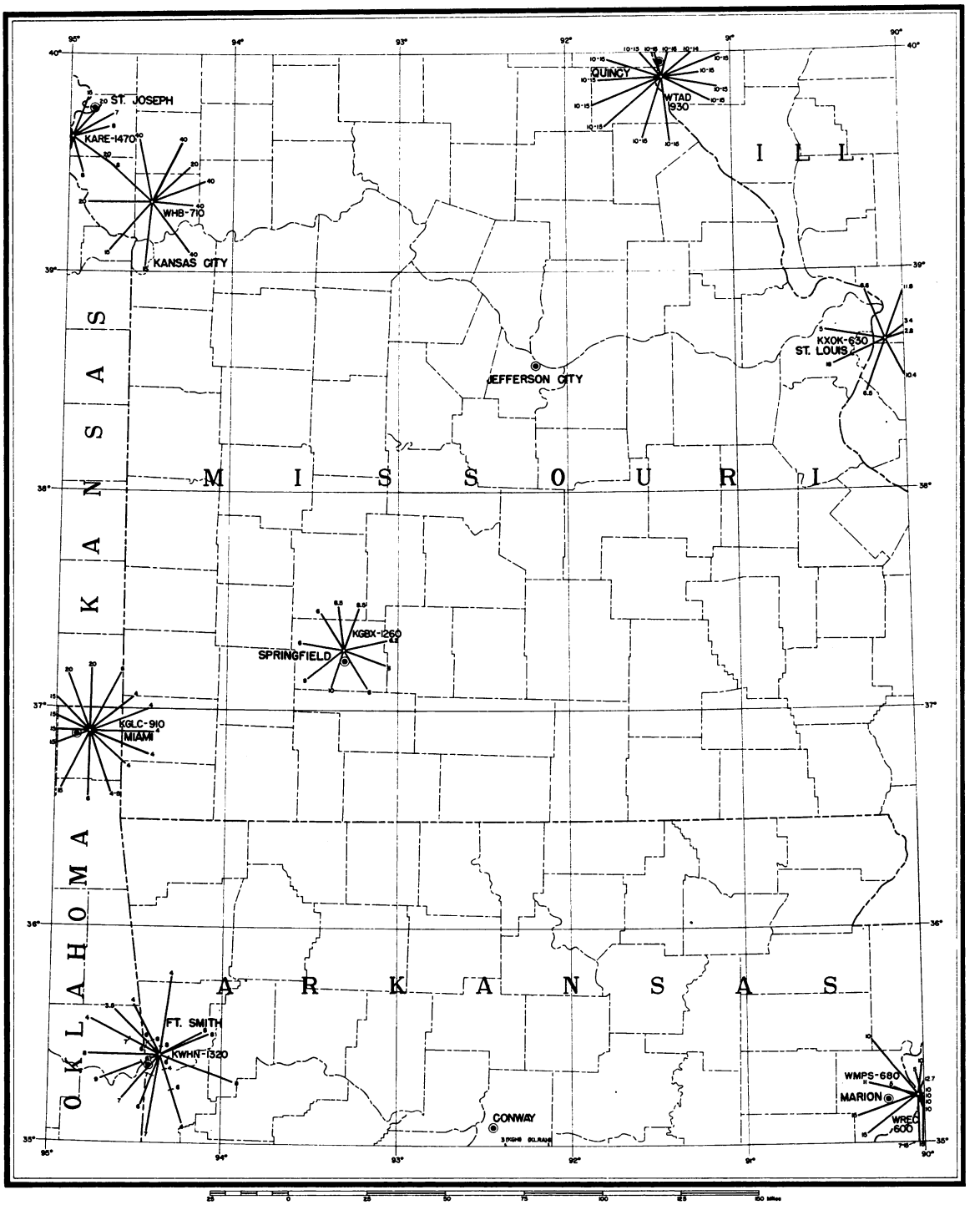
Map 28a.



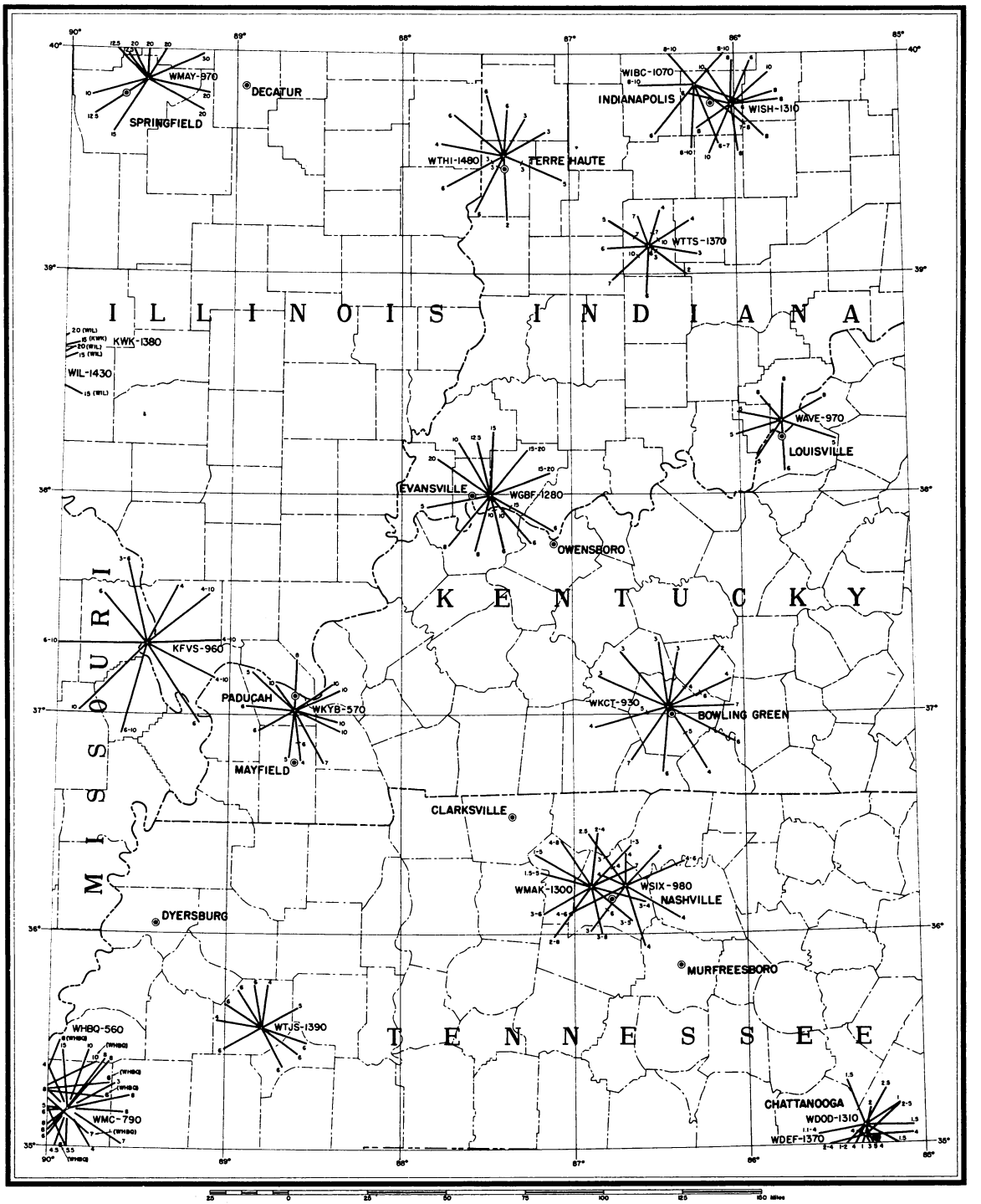
MAP 28b.



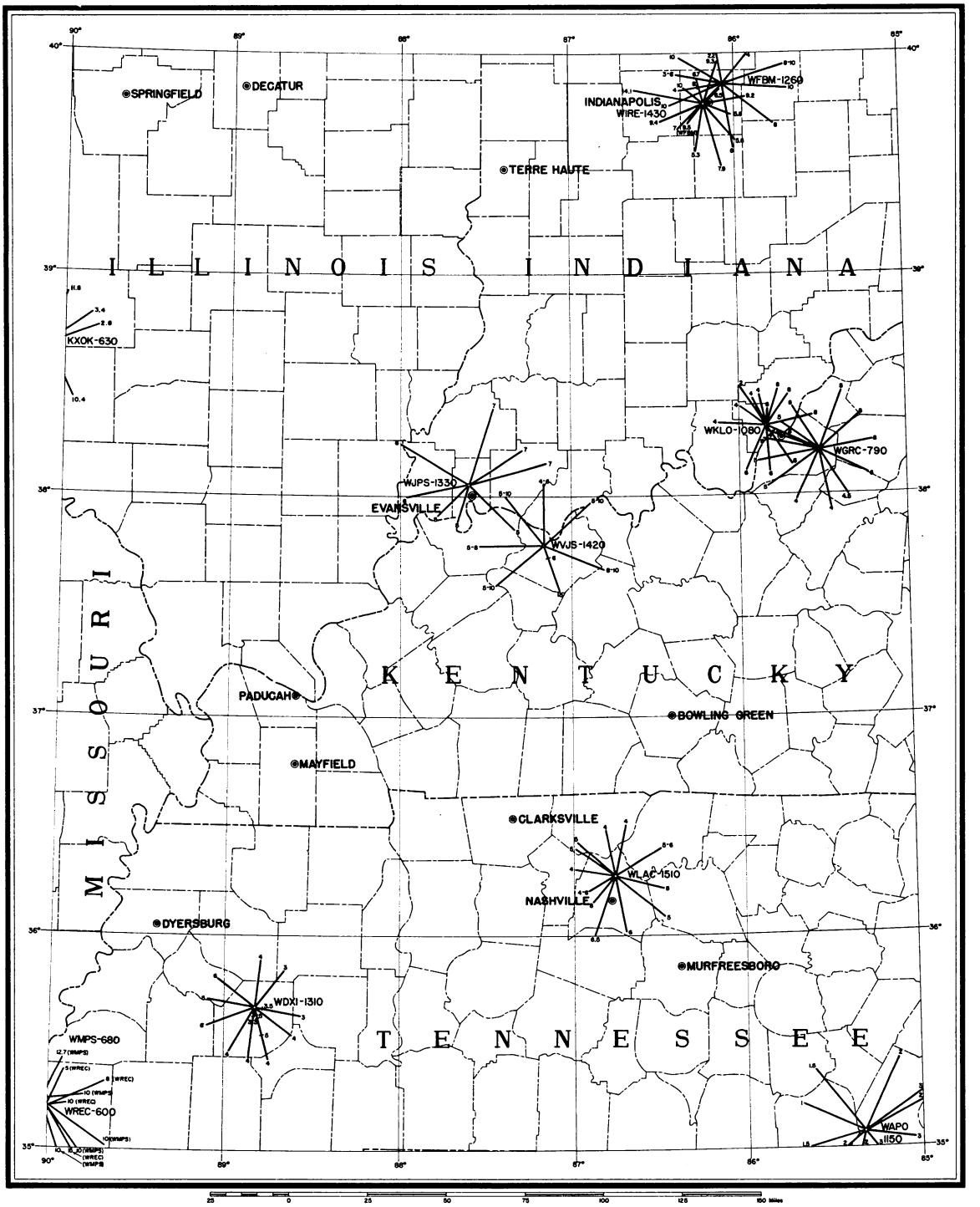
Map 29a.



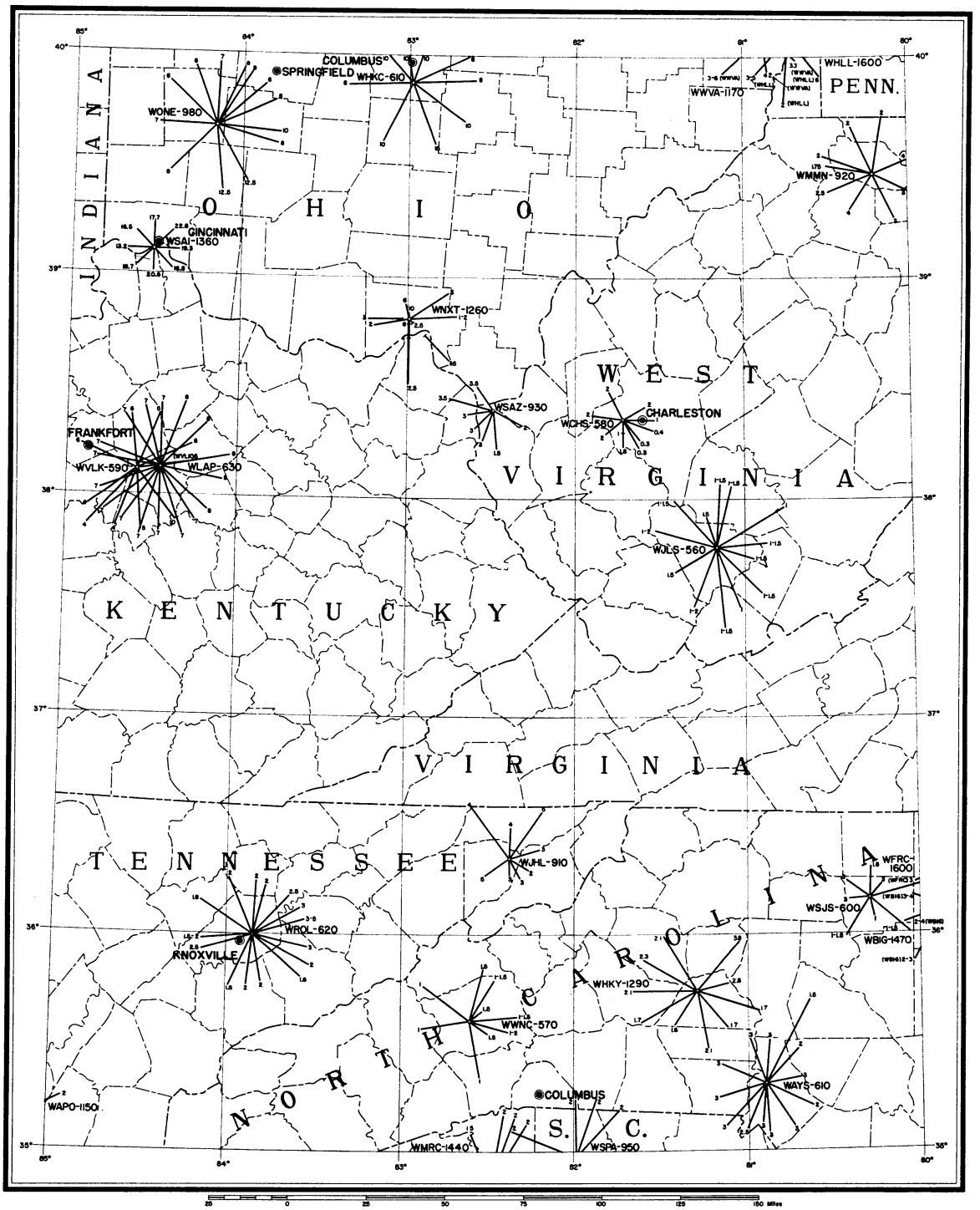
MAP 29b.



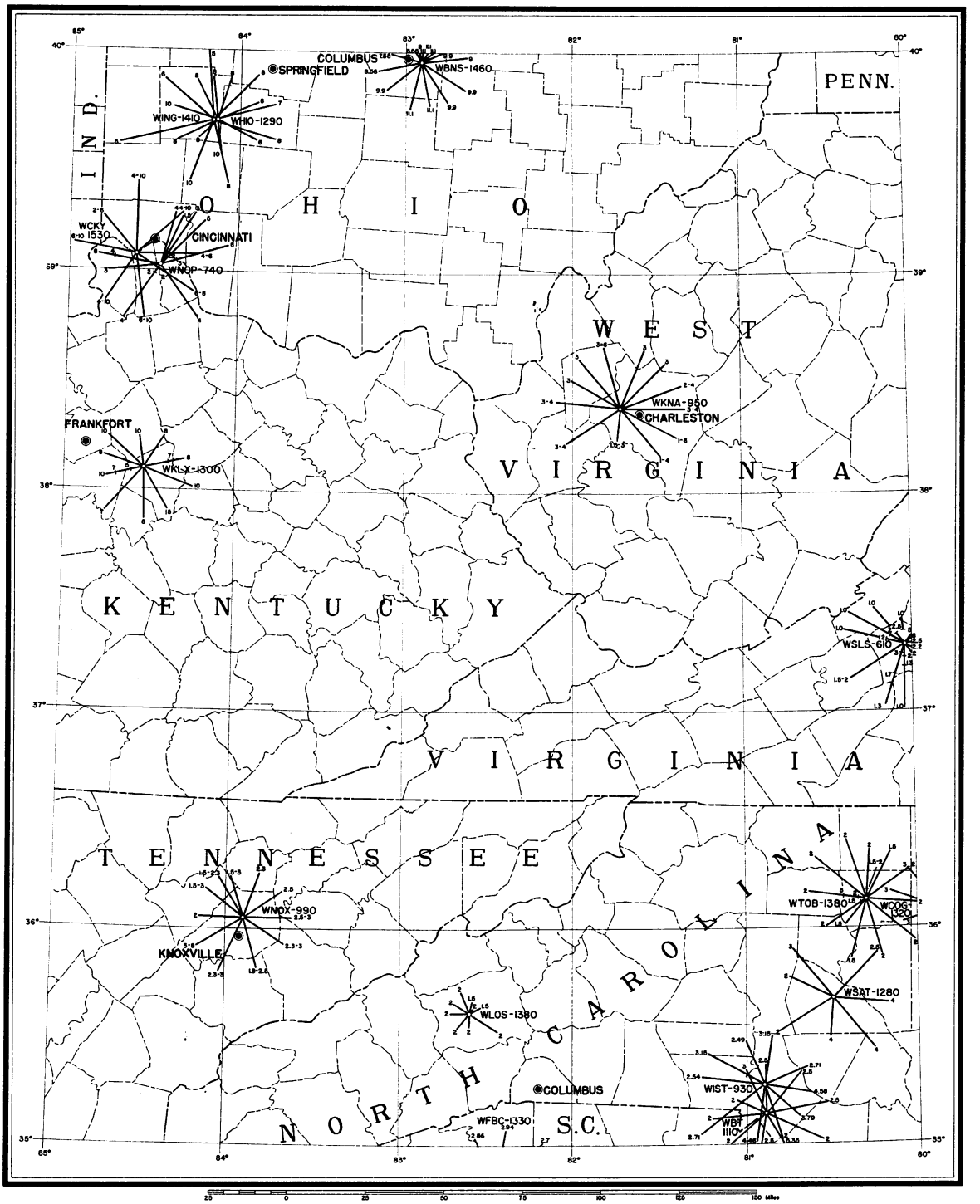
Map 30a.



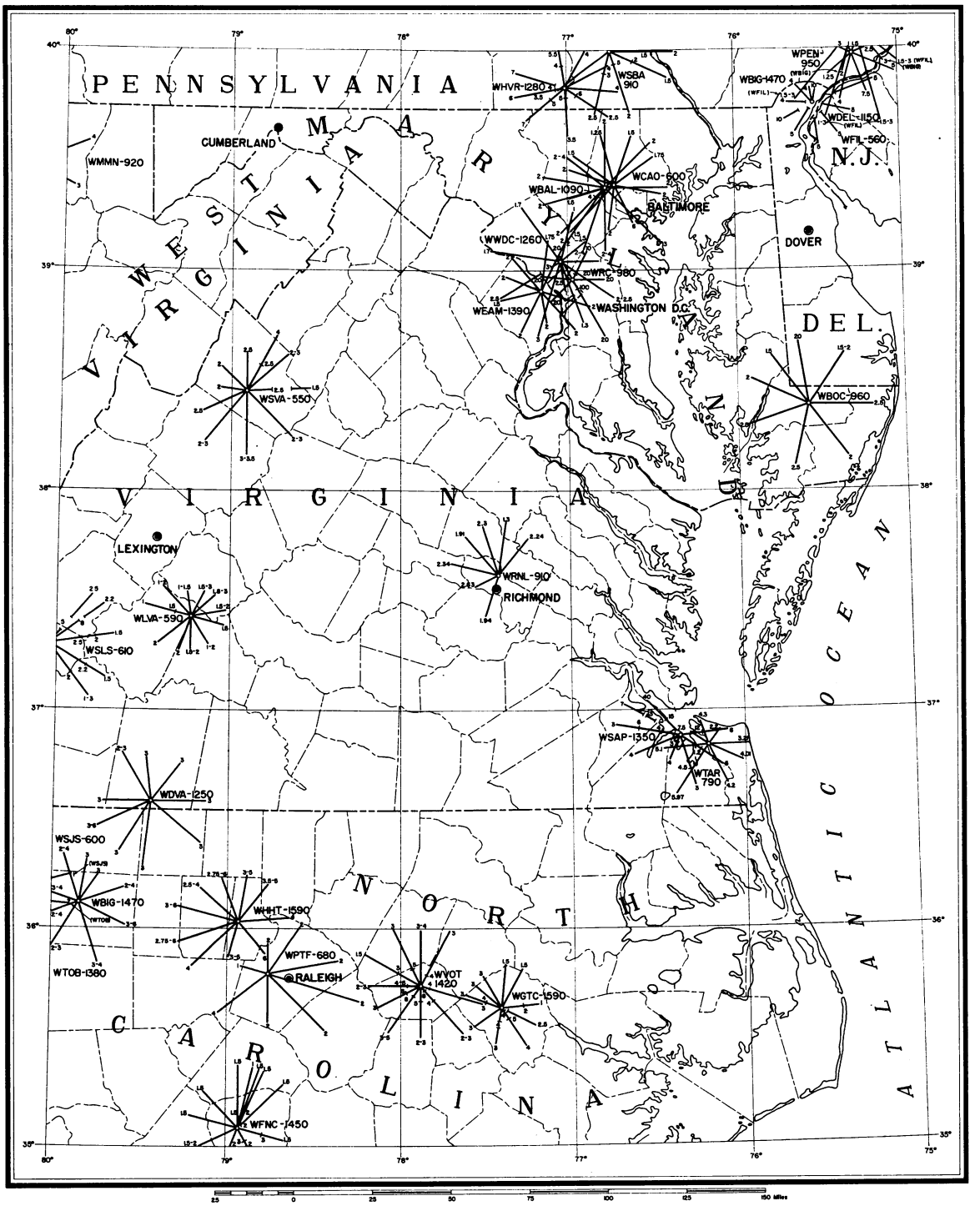
MAP 30b.



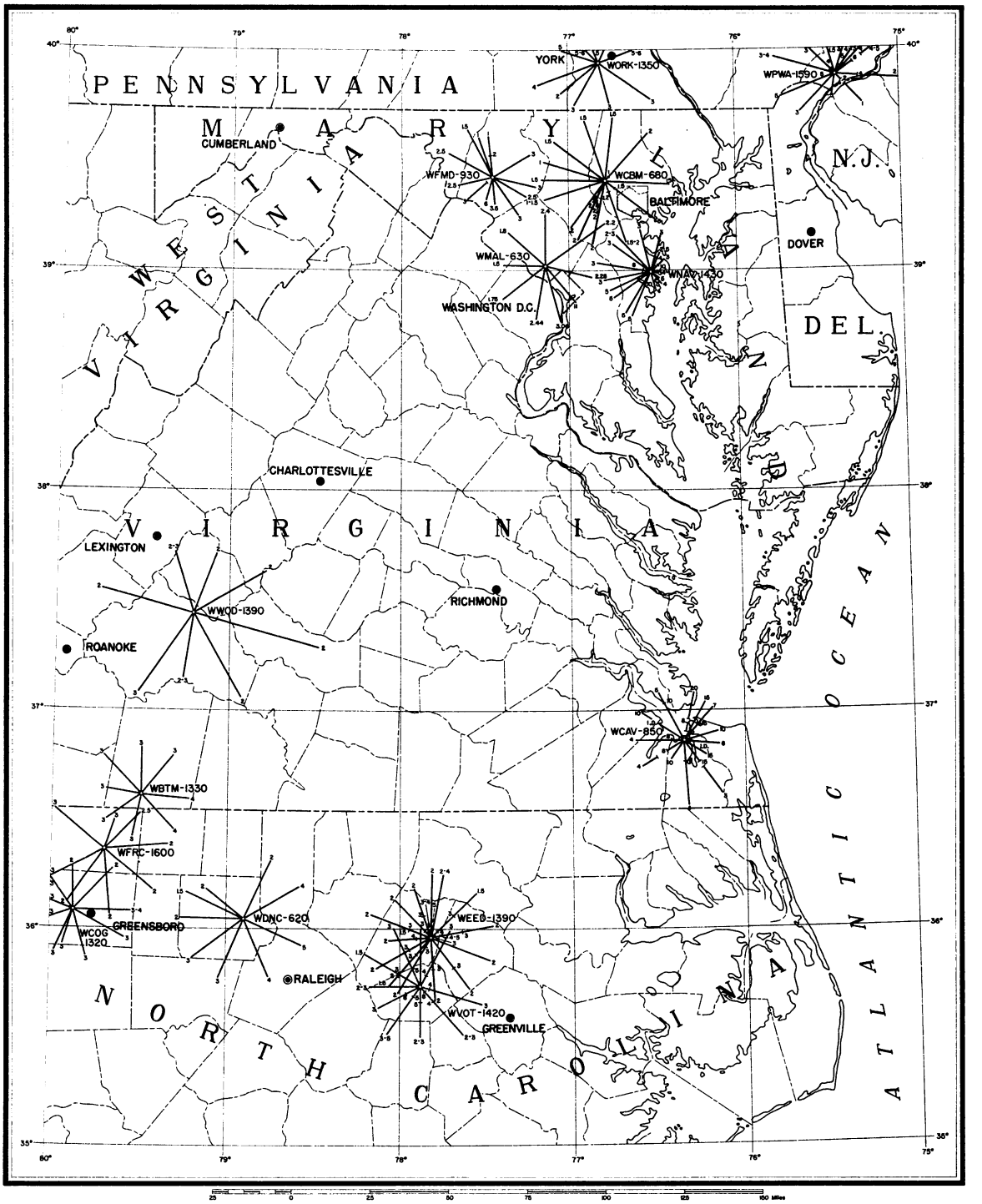
MAP 31a.



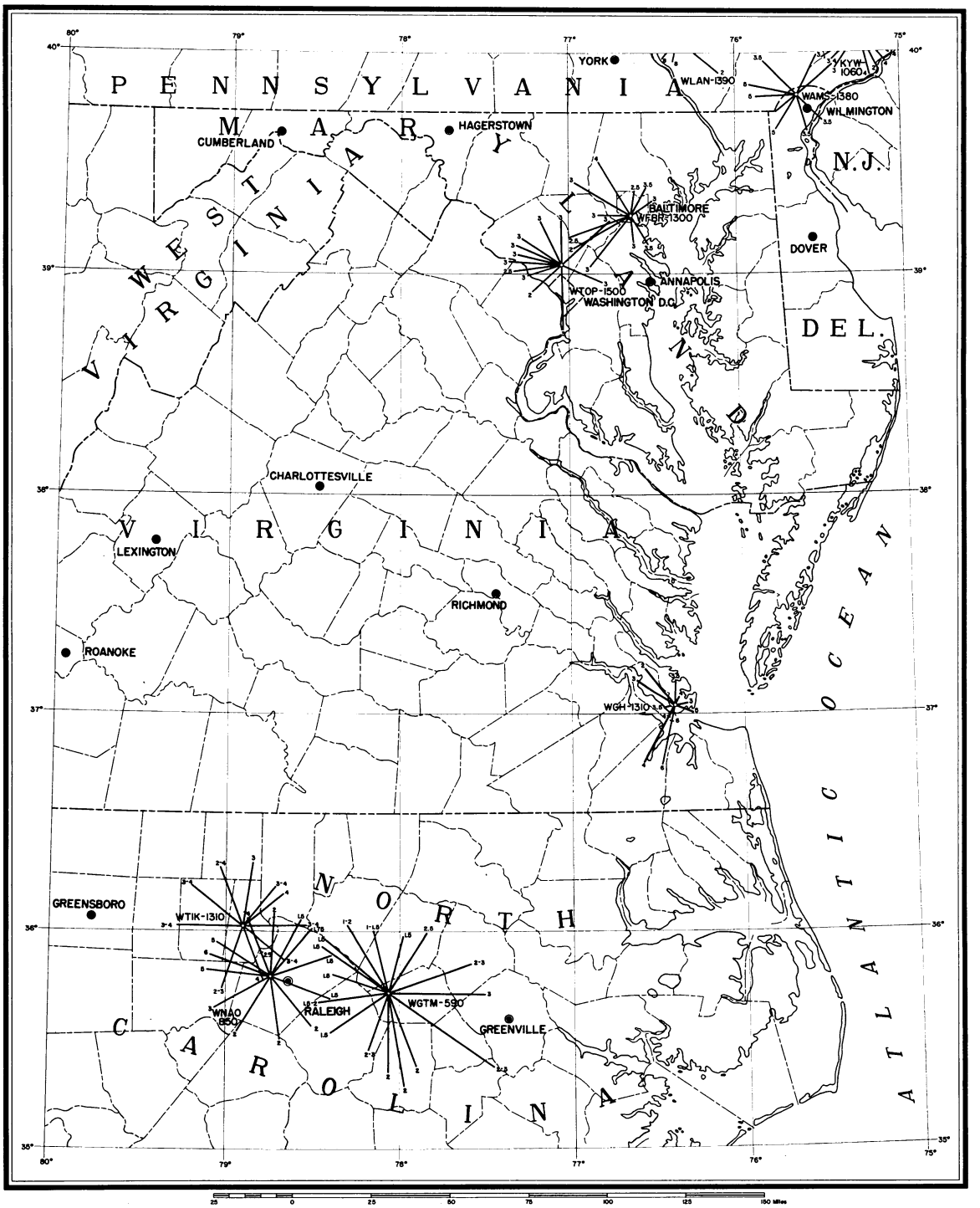
MAP 31b.



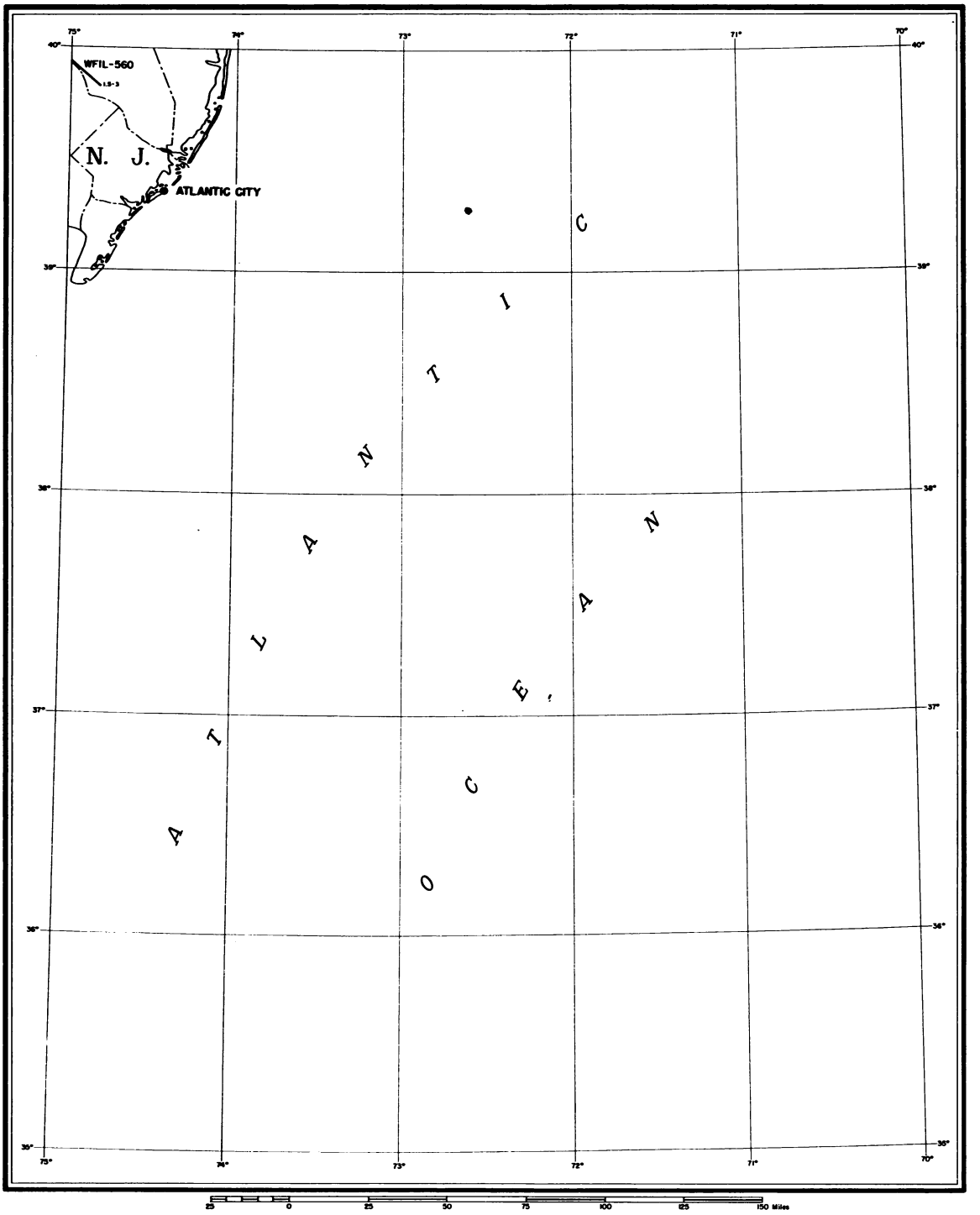
MAP 32a.



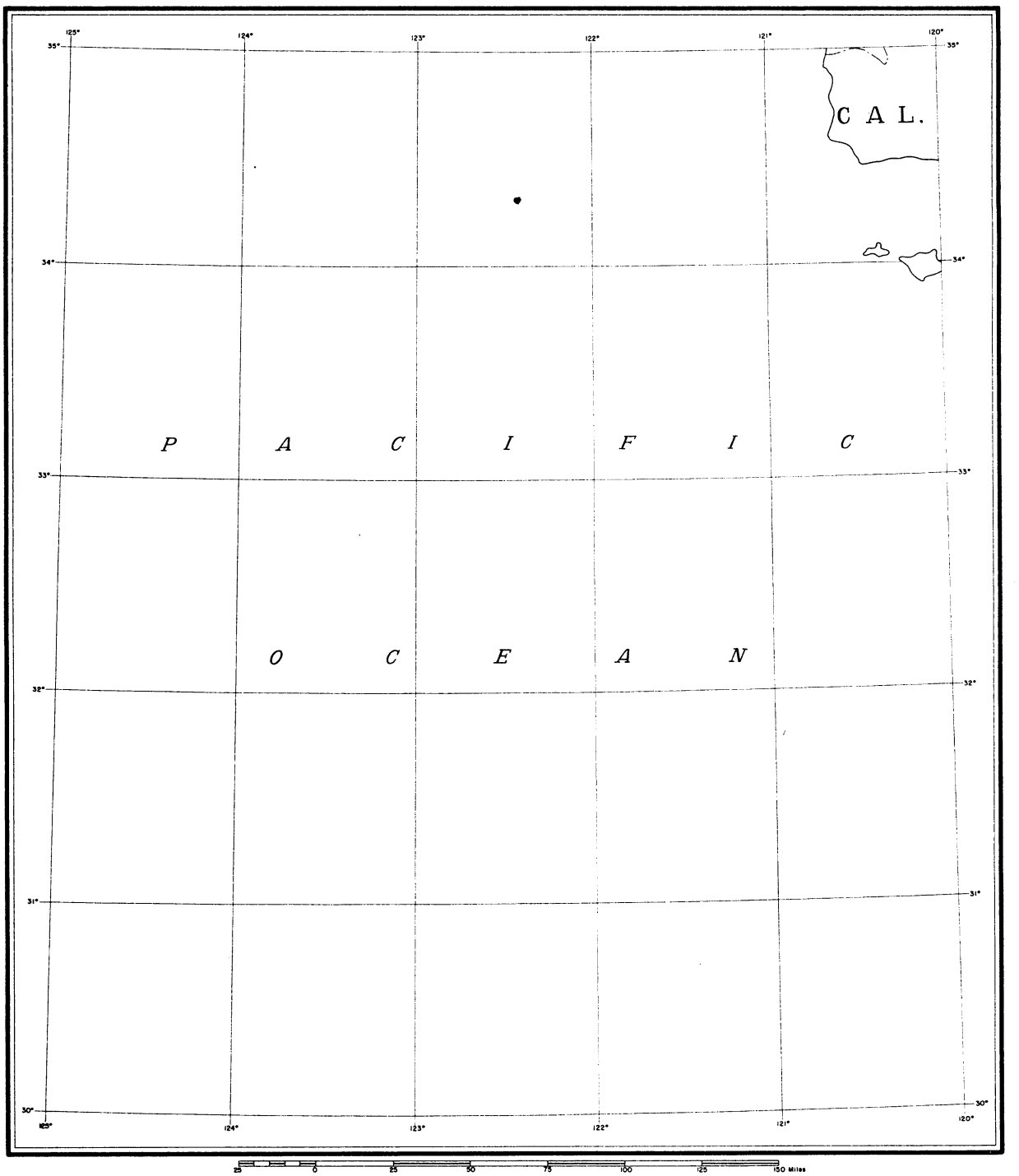
MAP 32b.



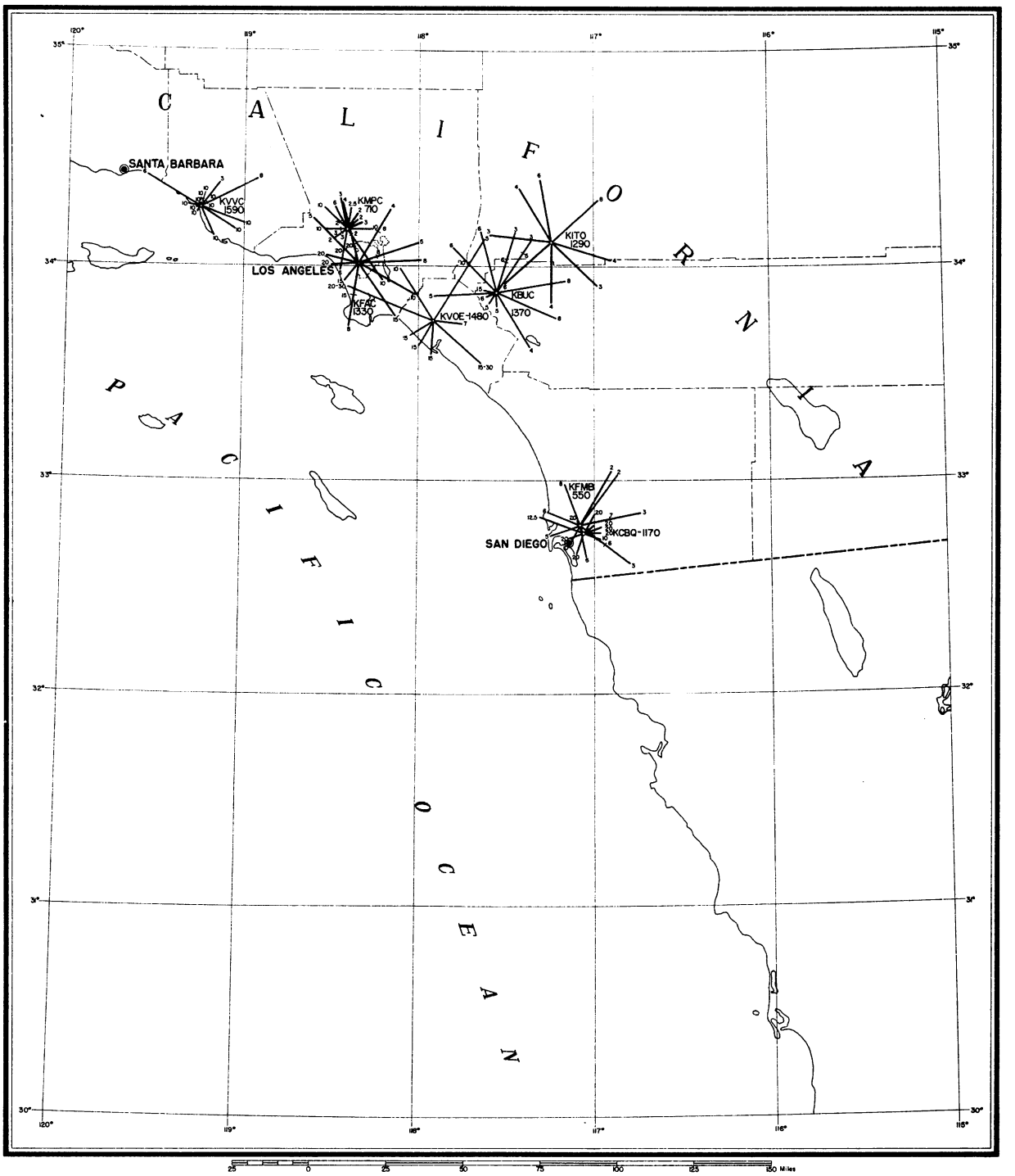
MAP 32c.



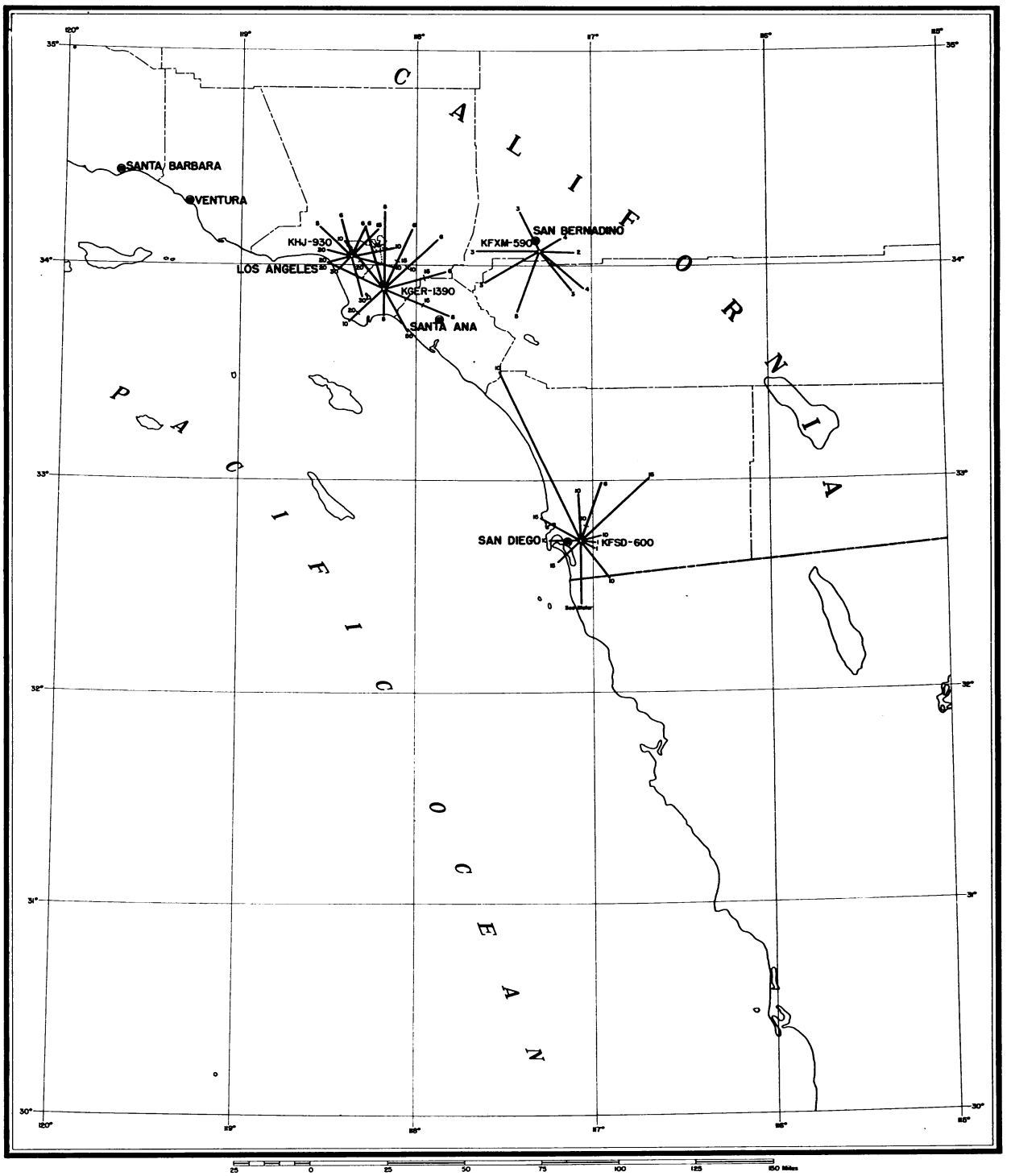
MAP 33.



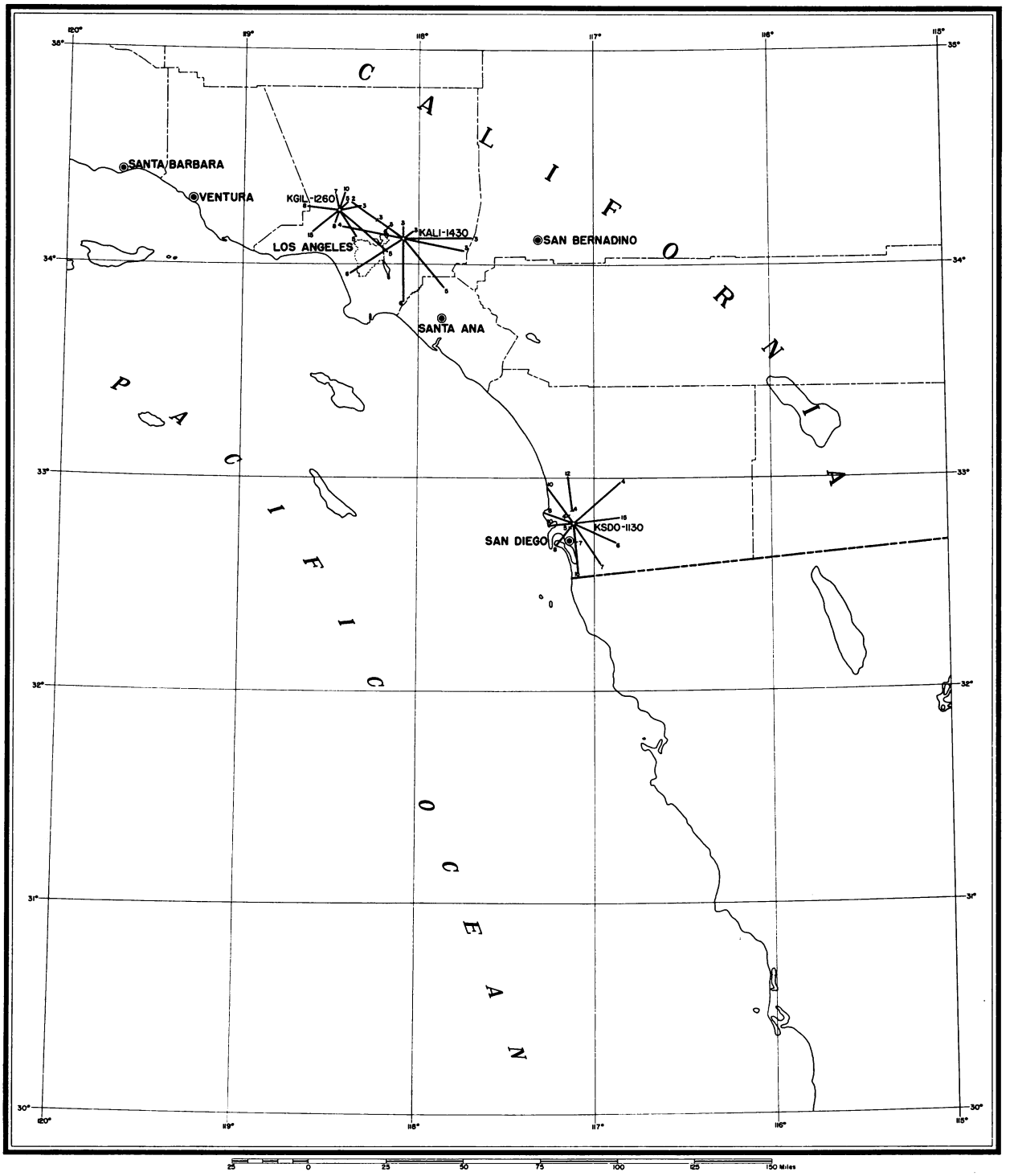
Map 34.



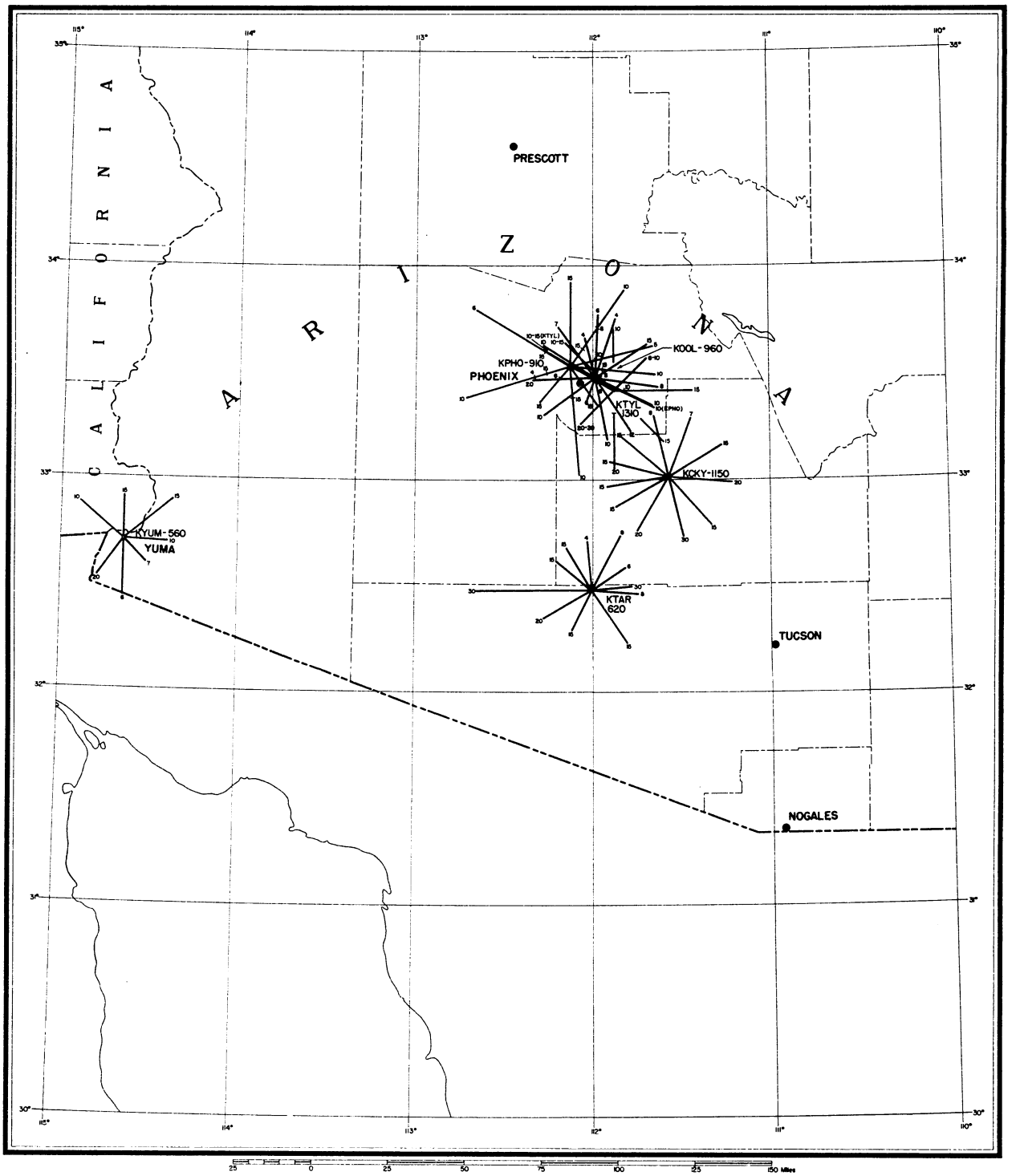
Map 35a.



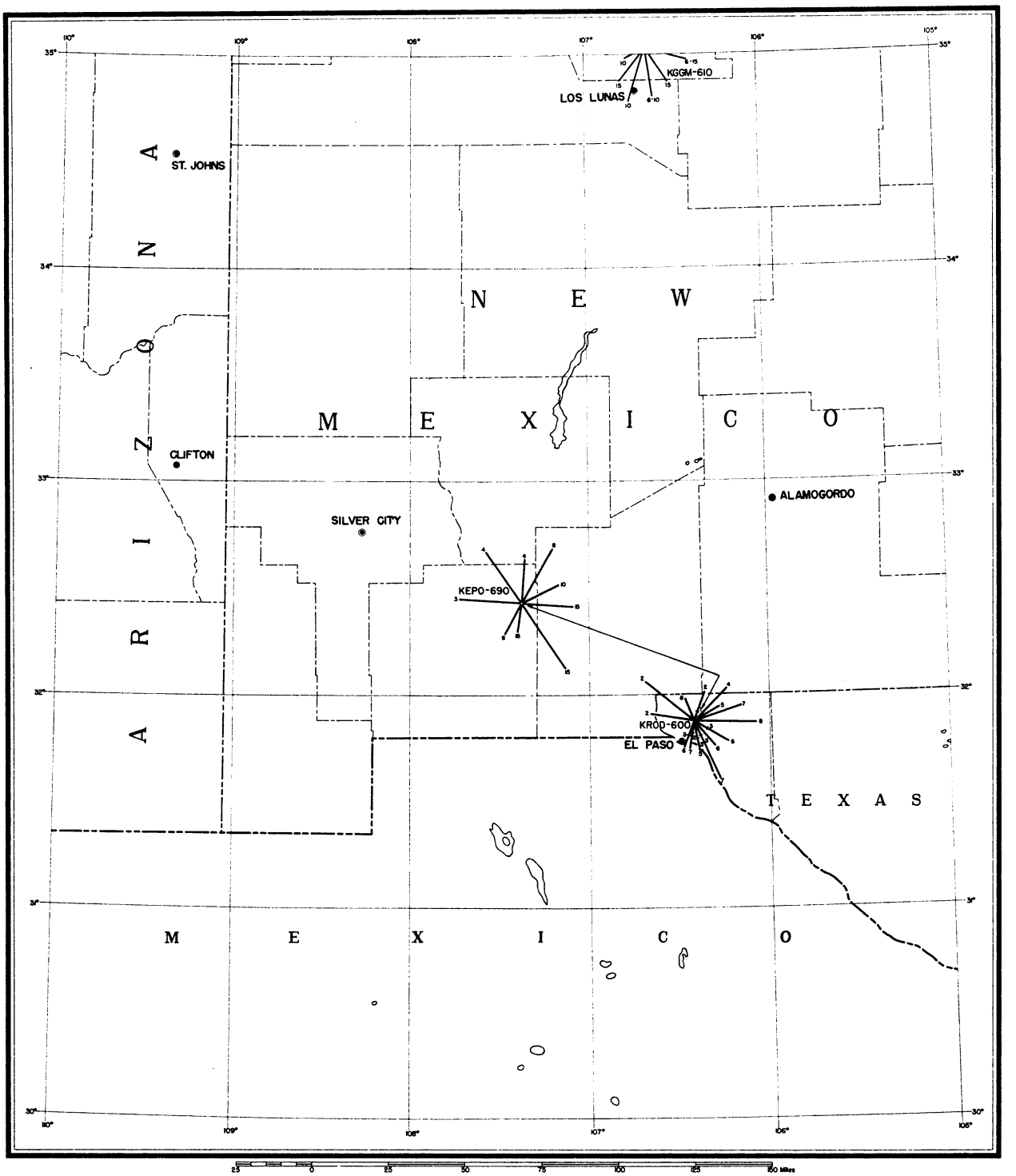
MAP 35b.



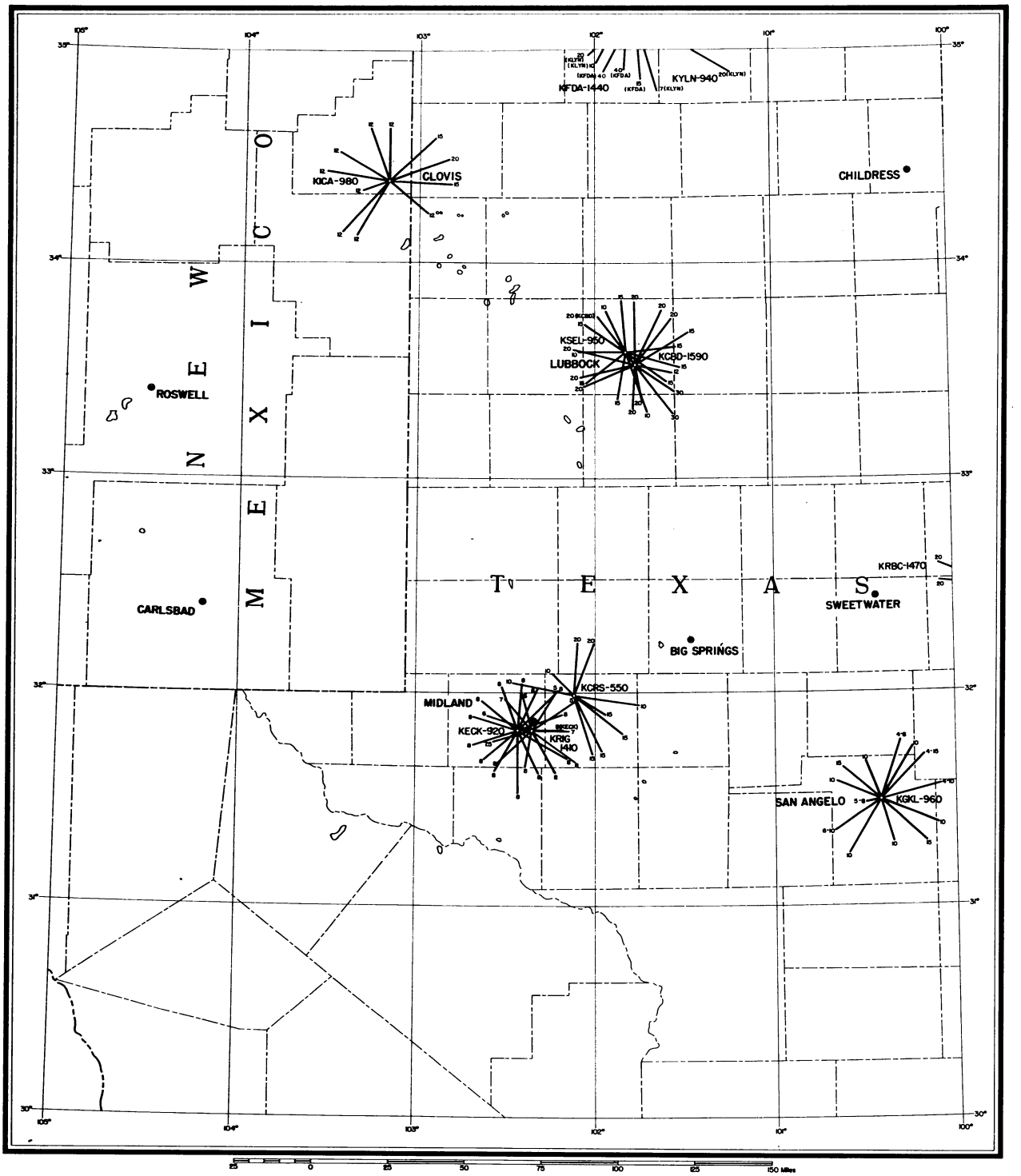
Map 35c.



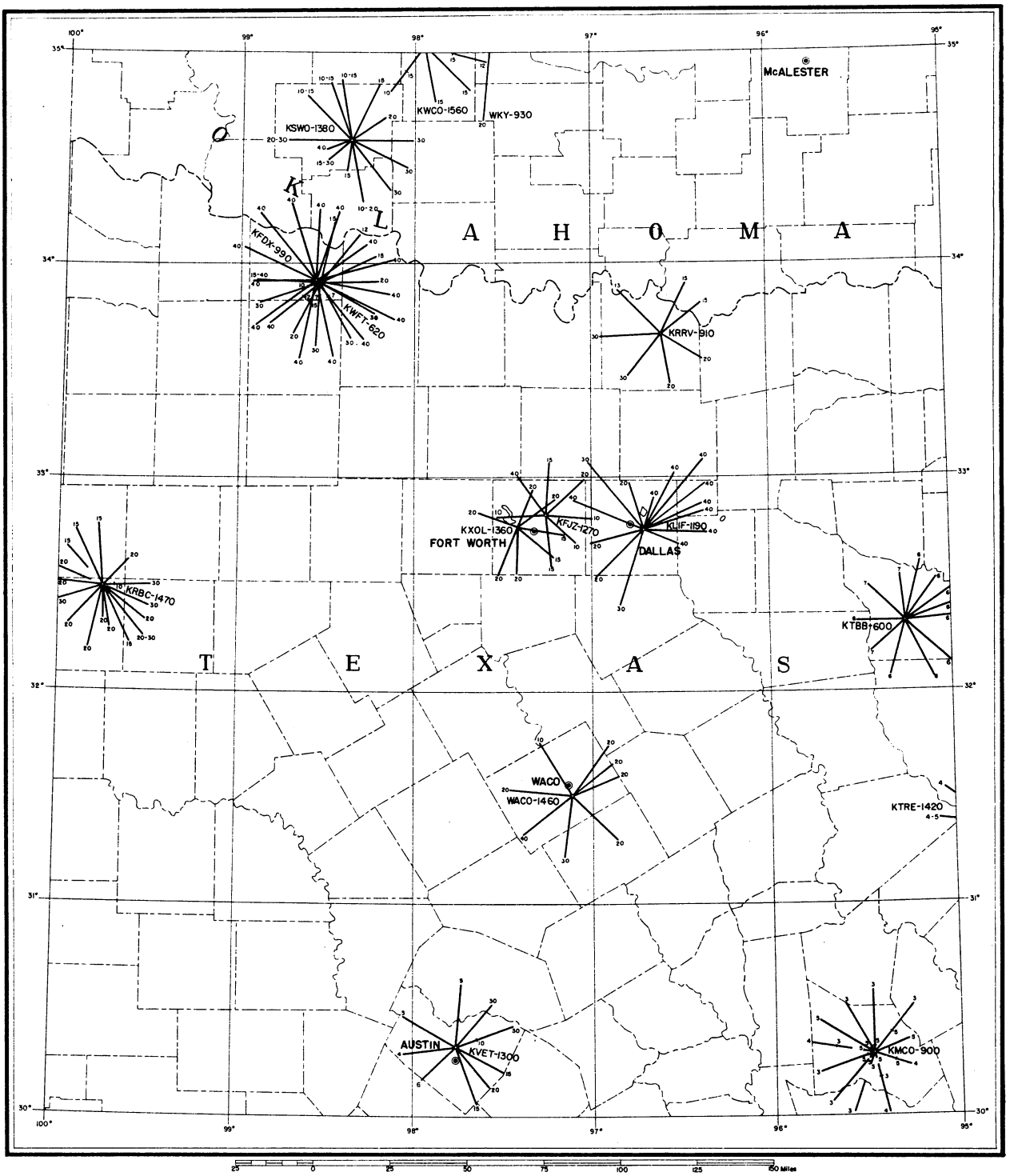
Map 36.



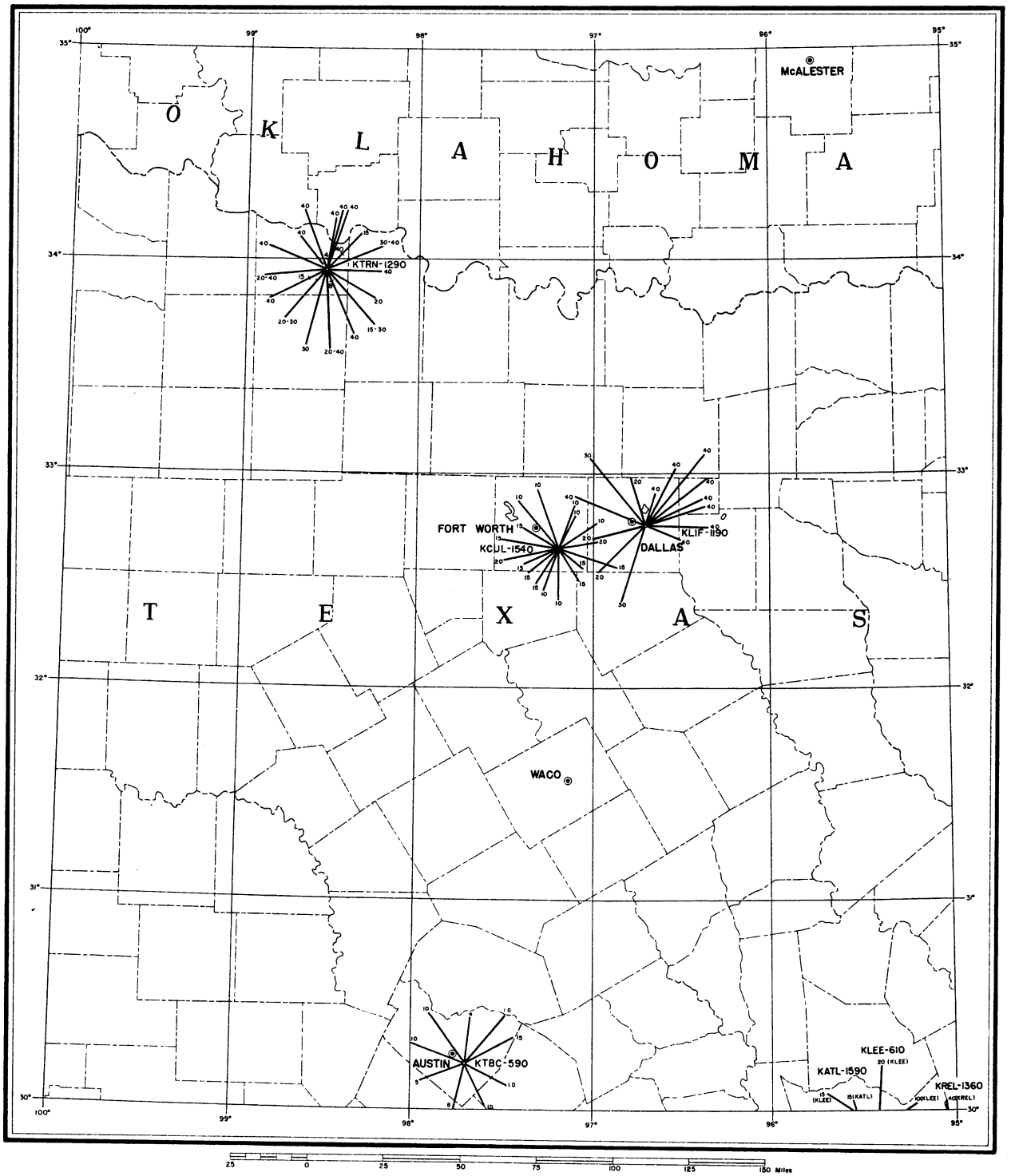
MAP 37.



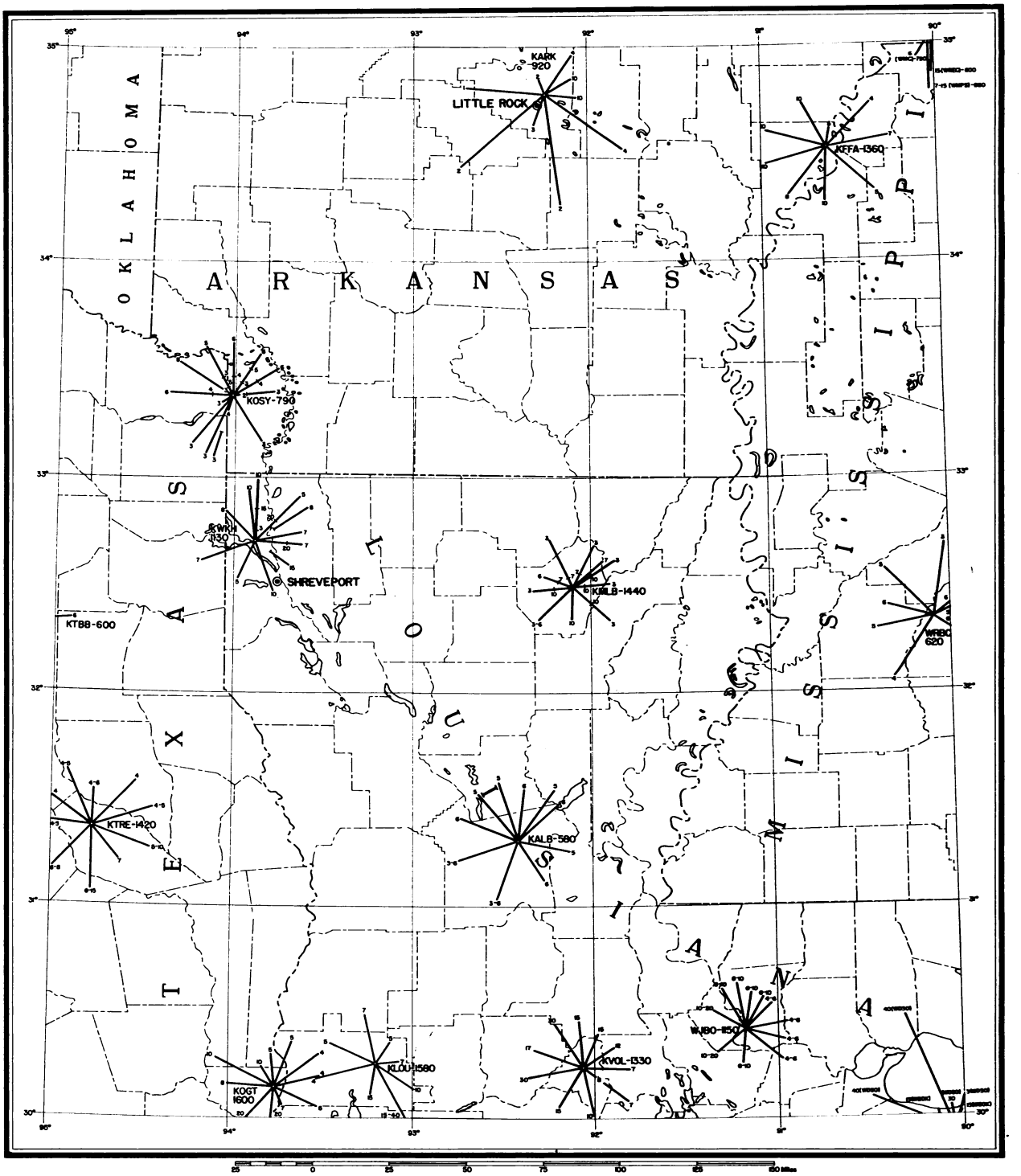
MAP 38.



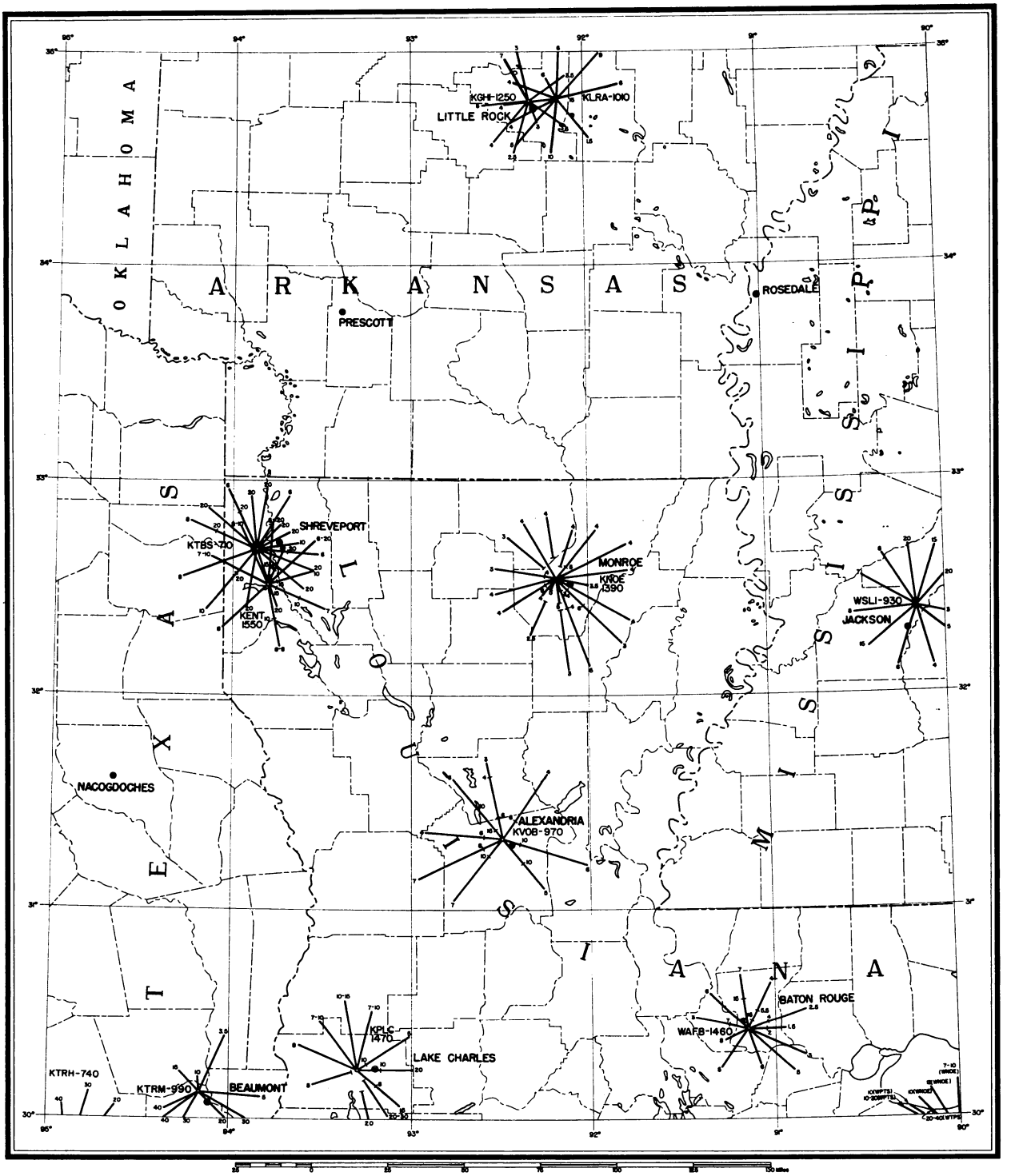
Map 39a.



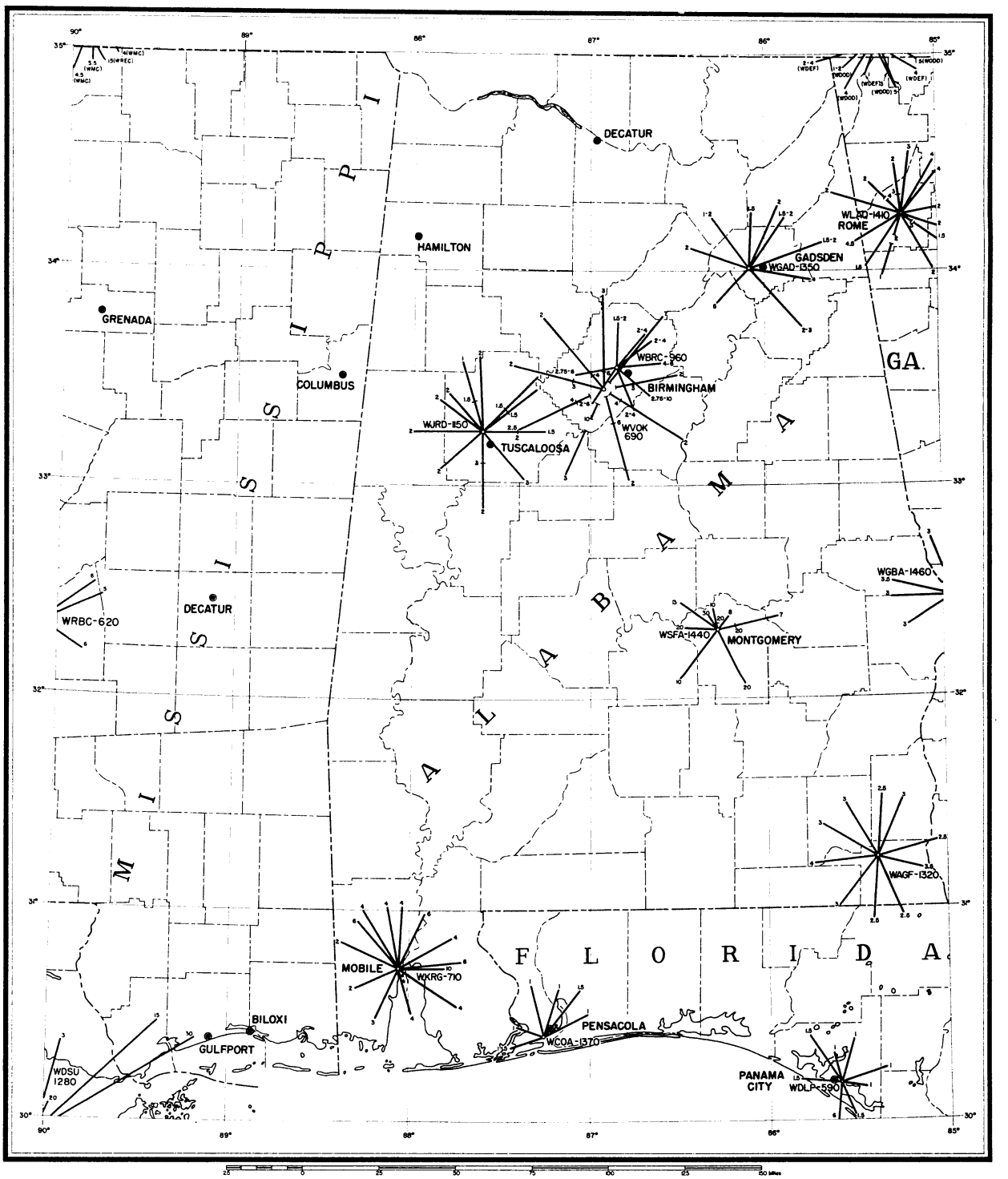
MAP 39b.



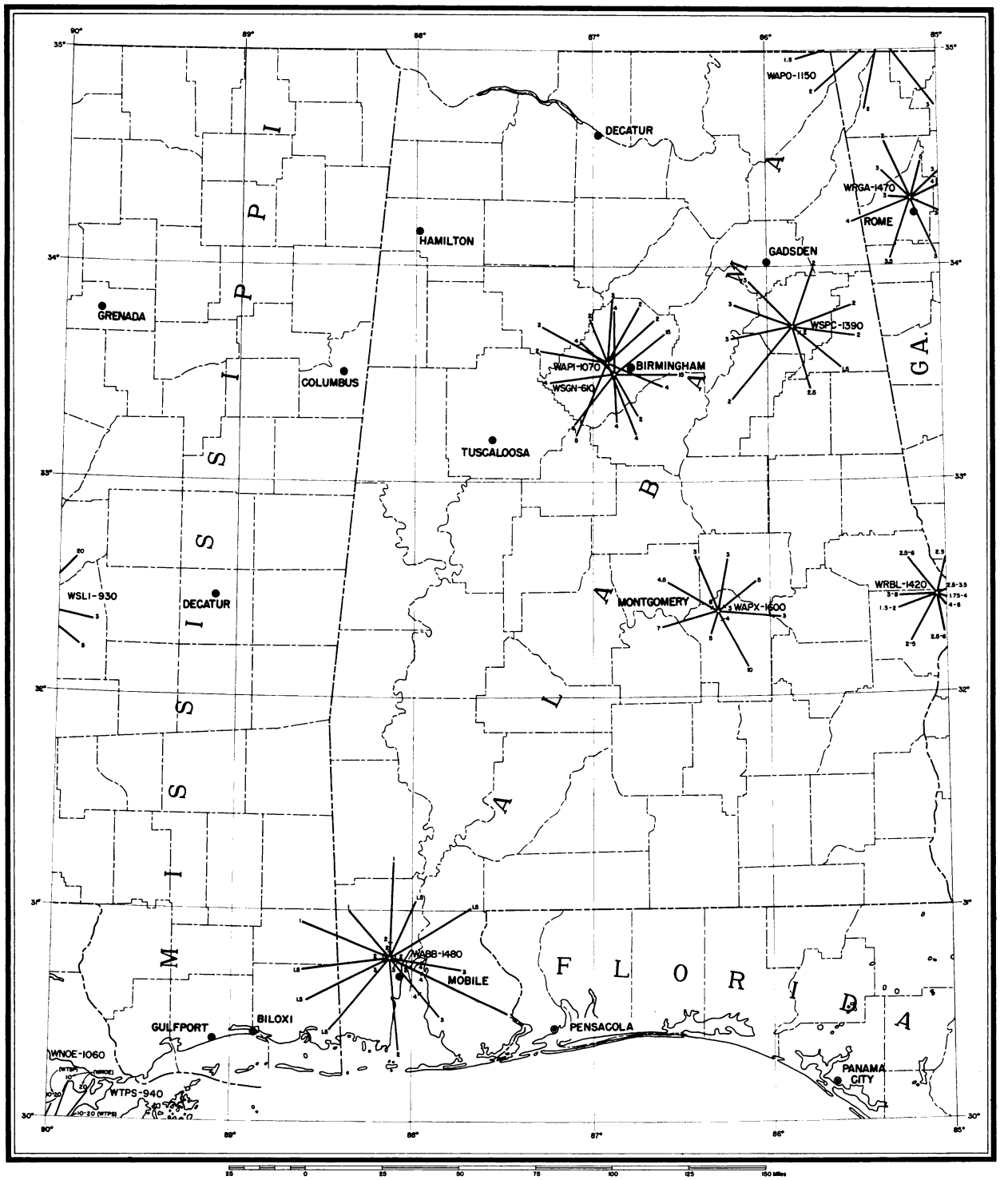
MAP 40a.



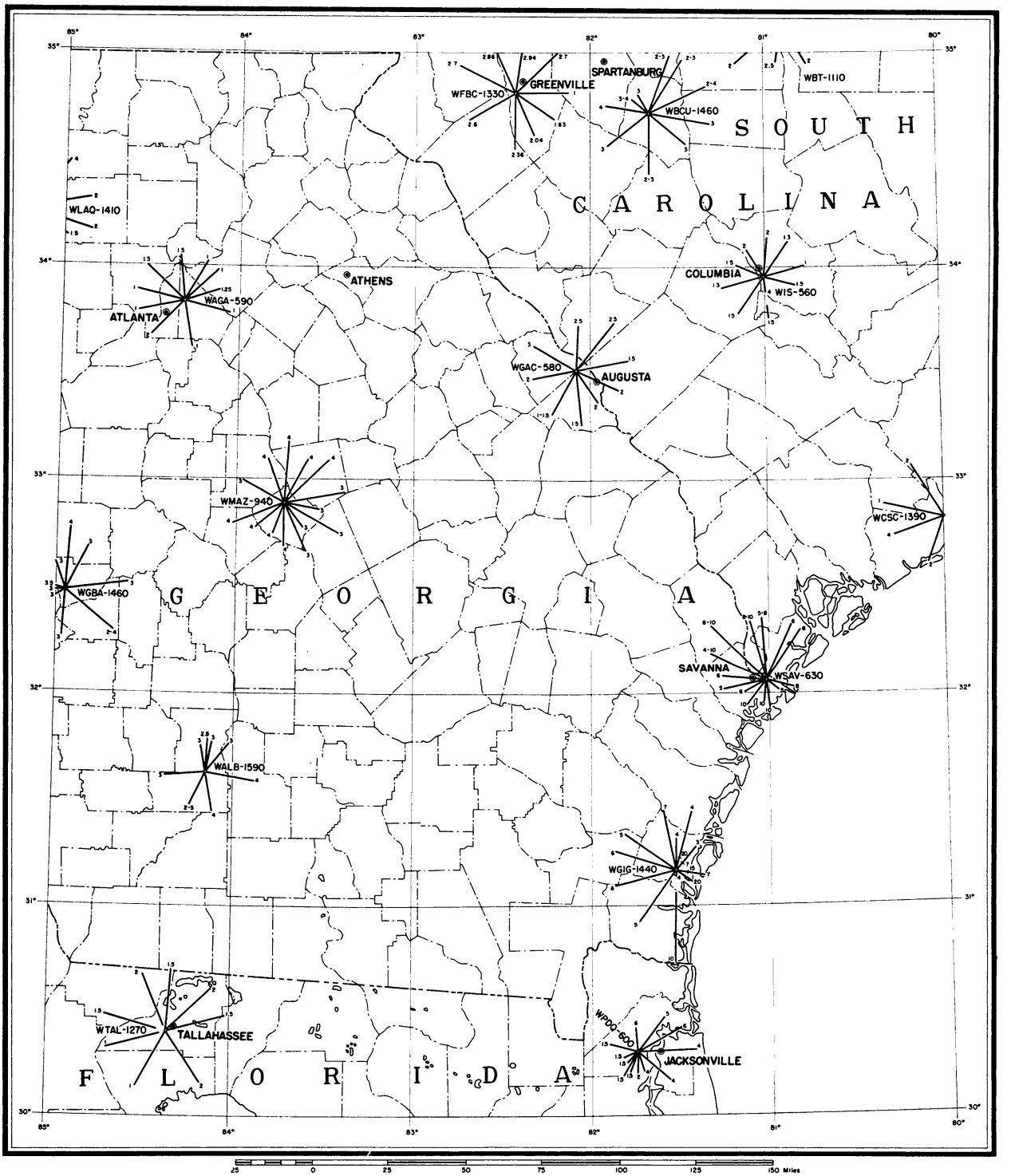
MAP 40b.



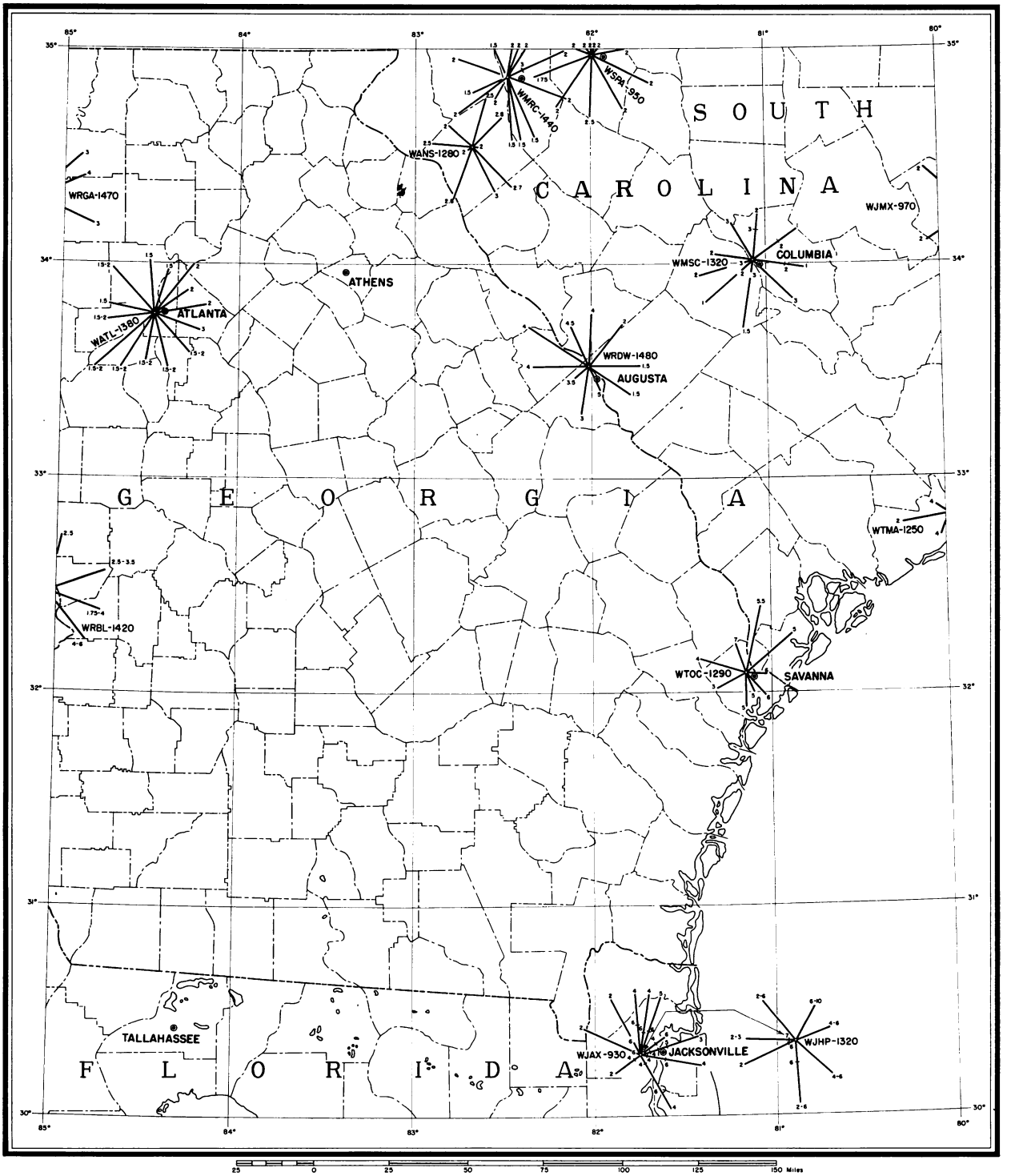
Map 41a.



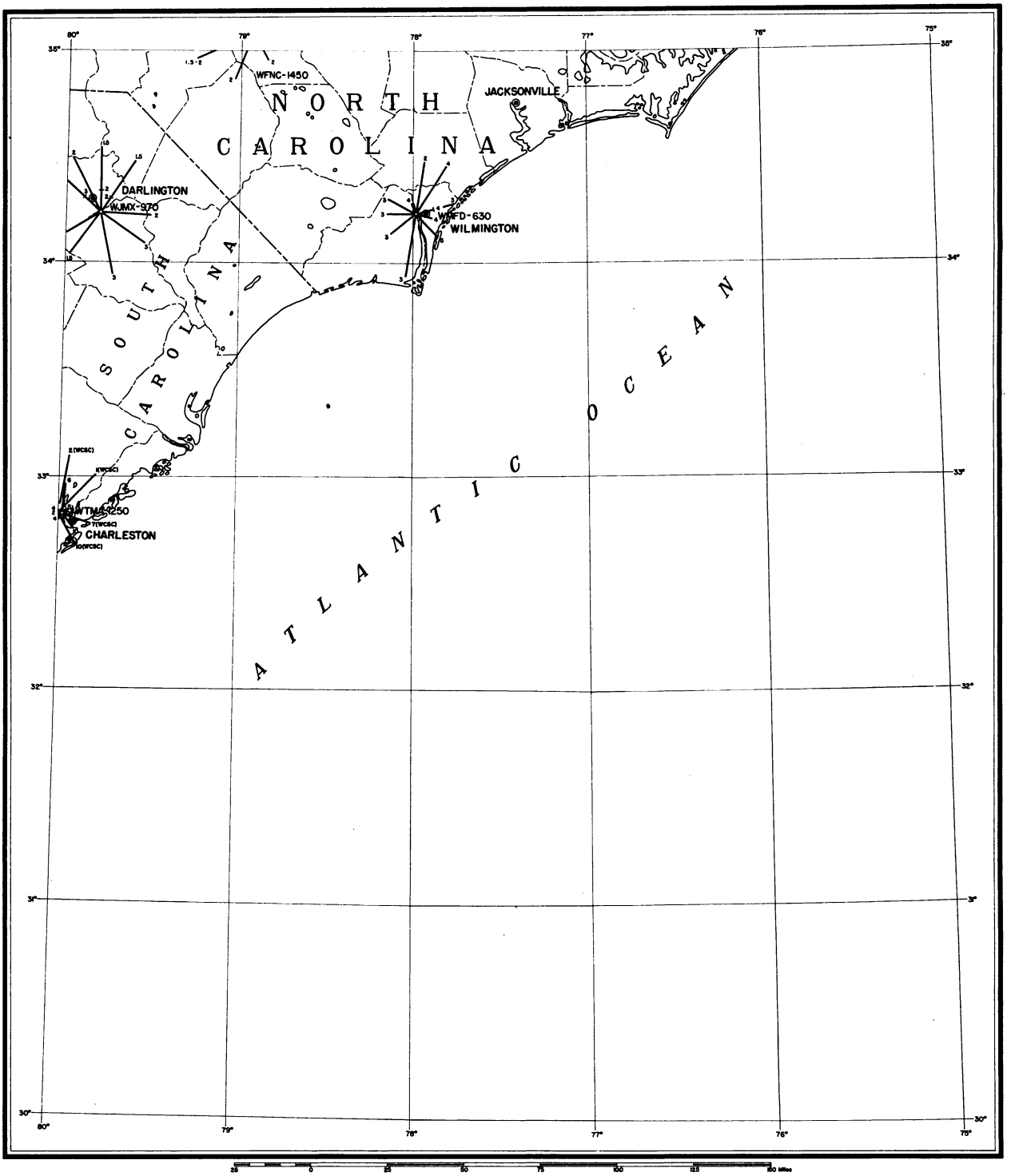
MAP 41b.



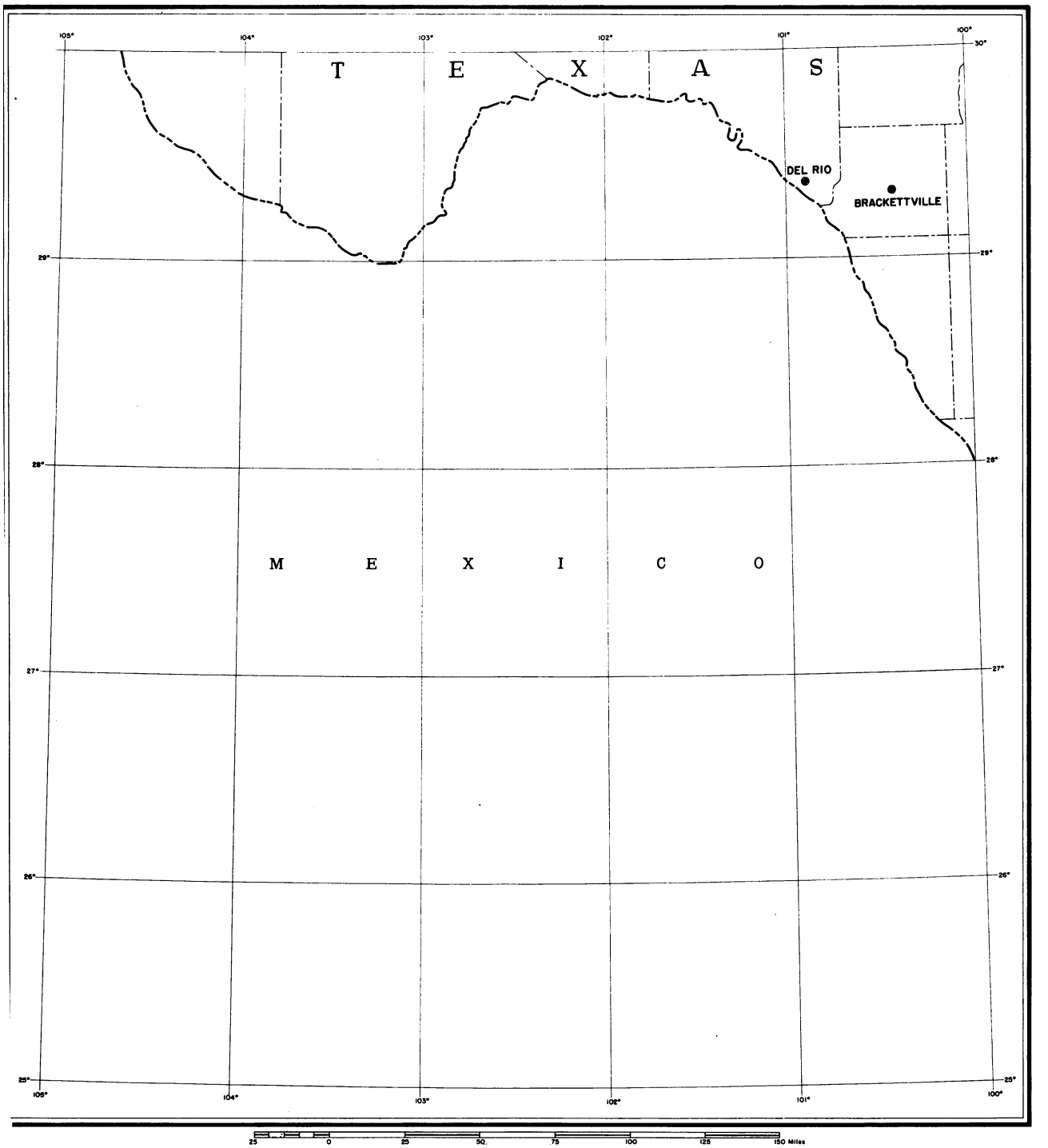
MAP 42a.



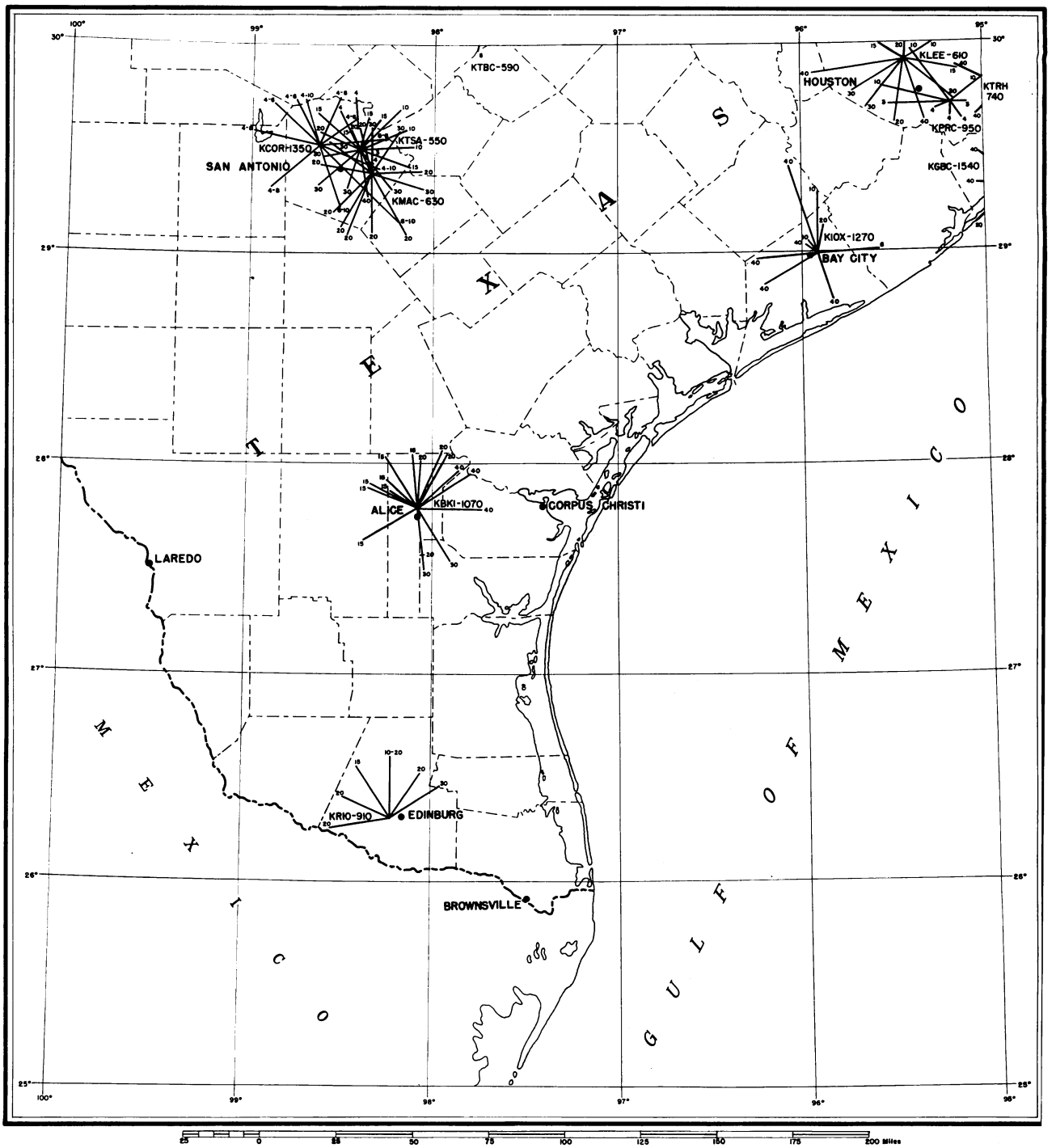
Map 42b.



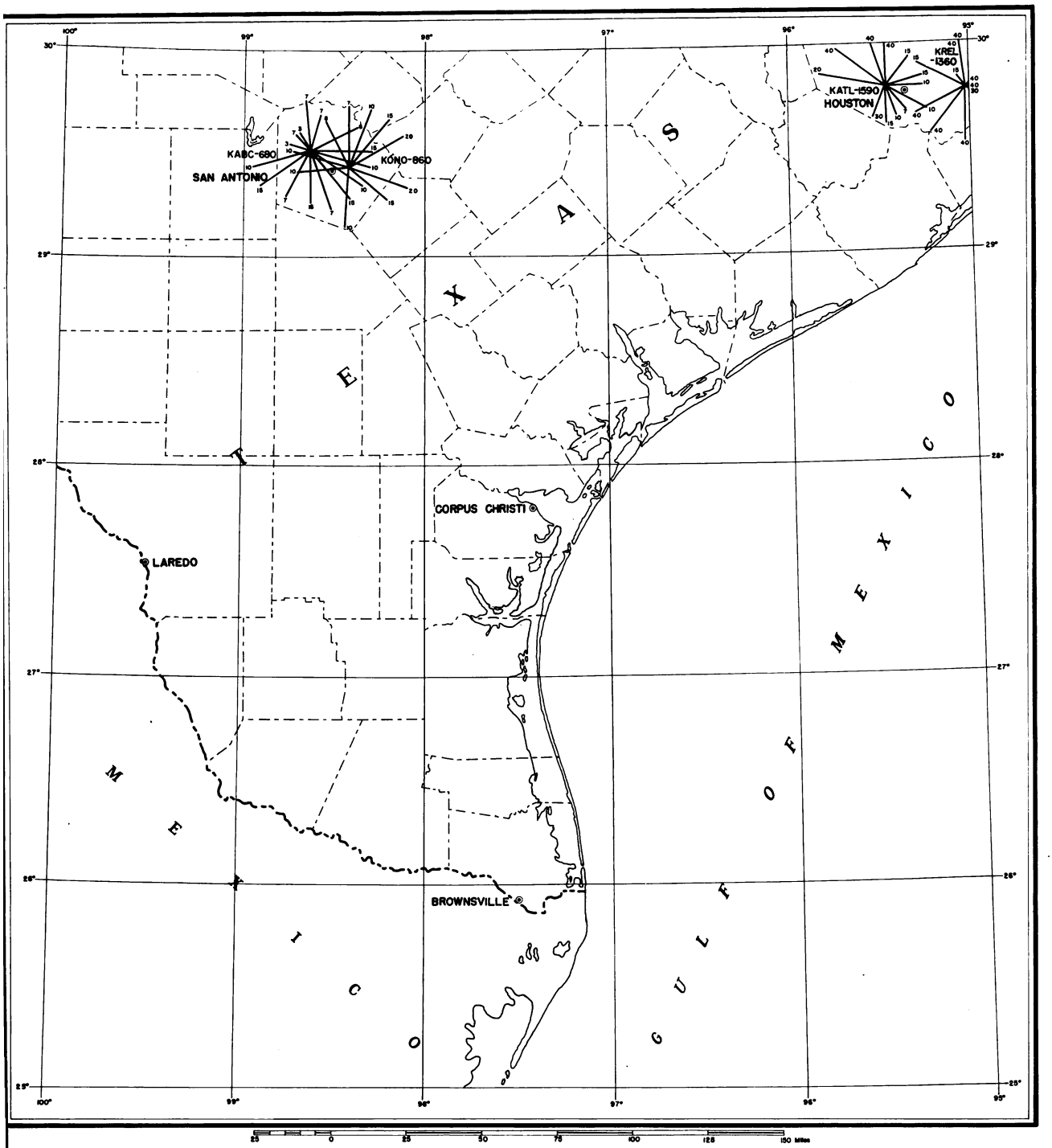
MAP 43.



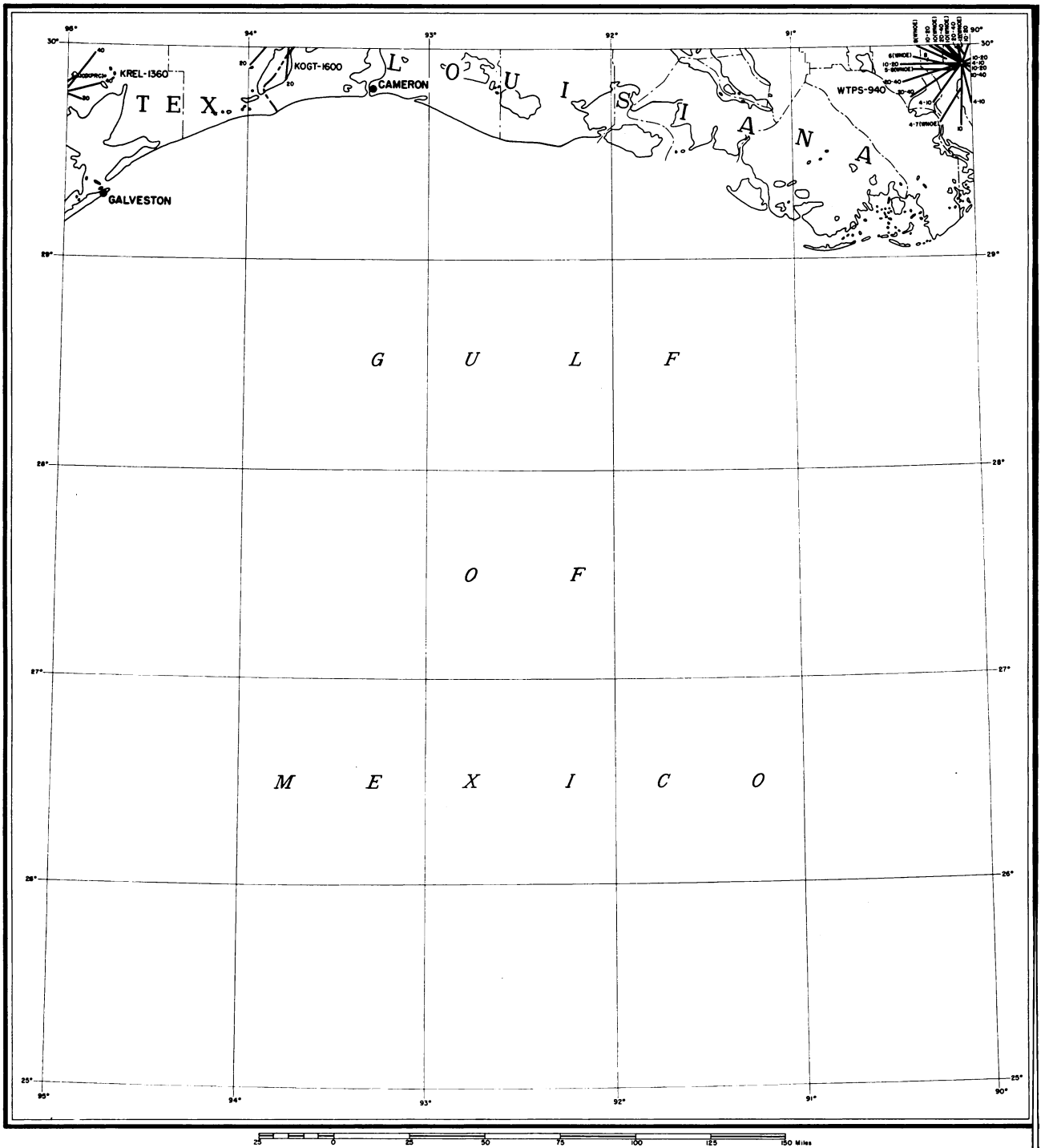
MAP 44.



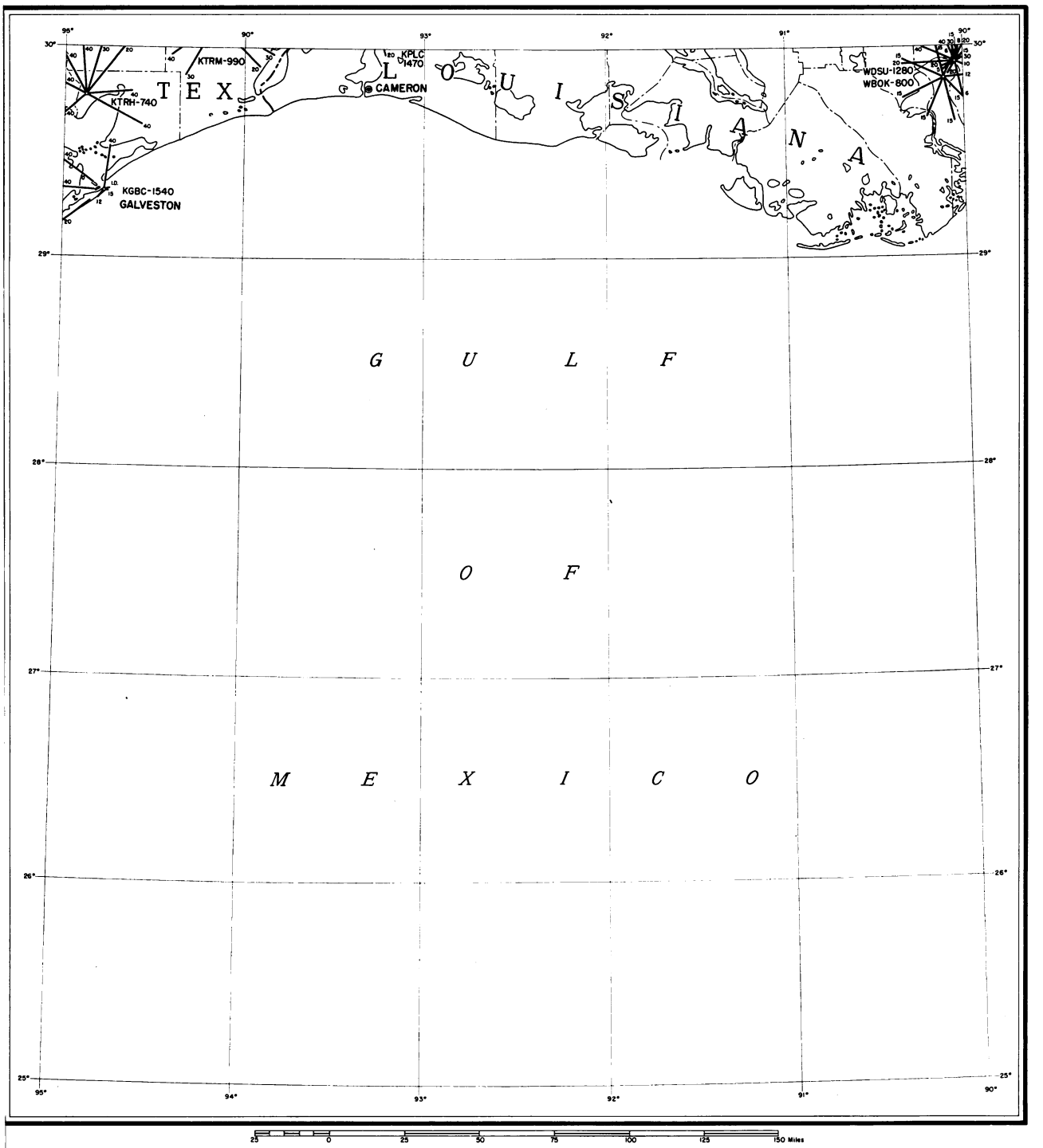
Map 45a.



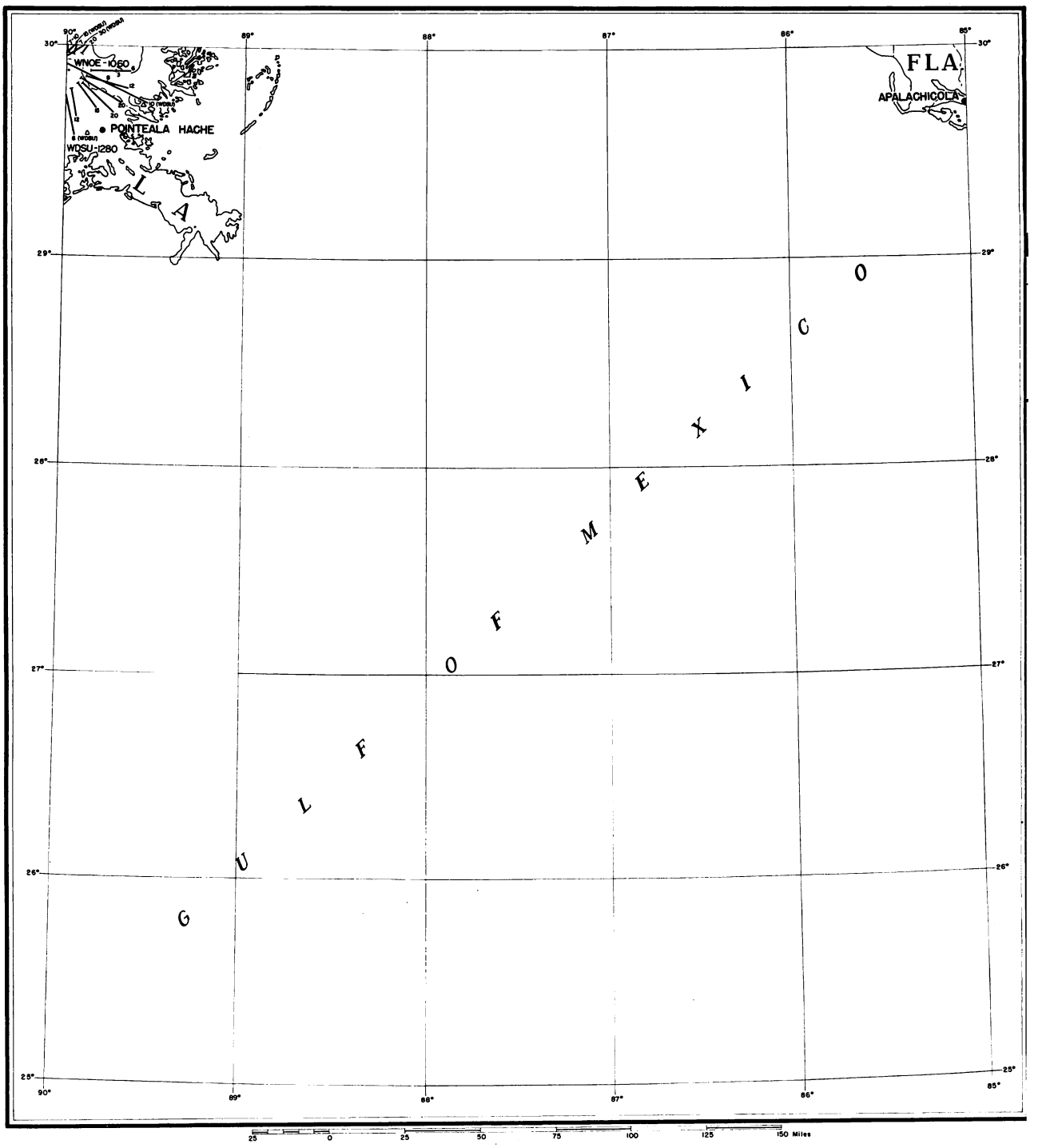
Map 45b.



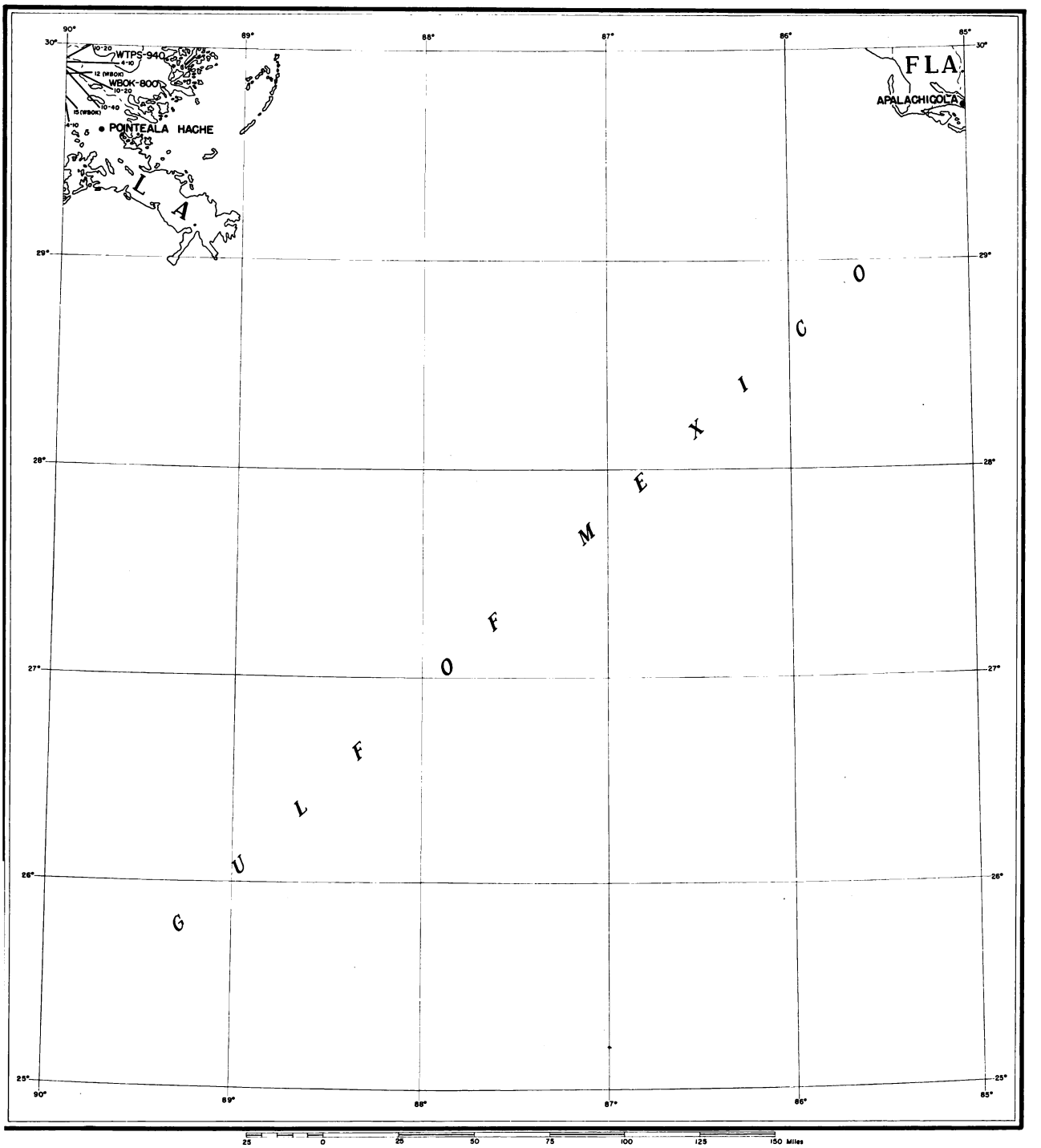
Map 46a.



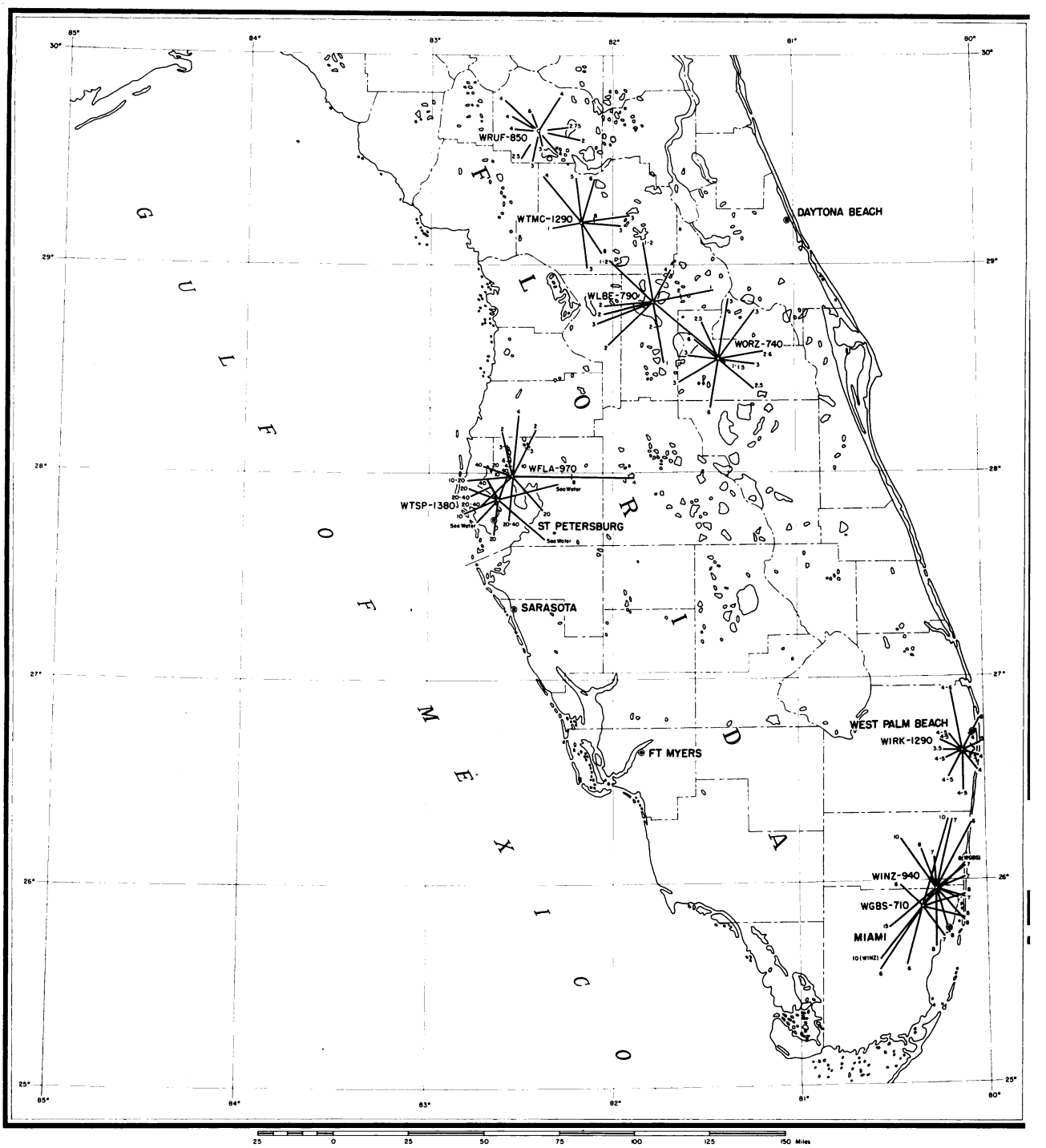
MAP 46b.



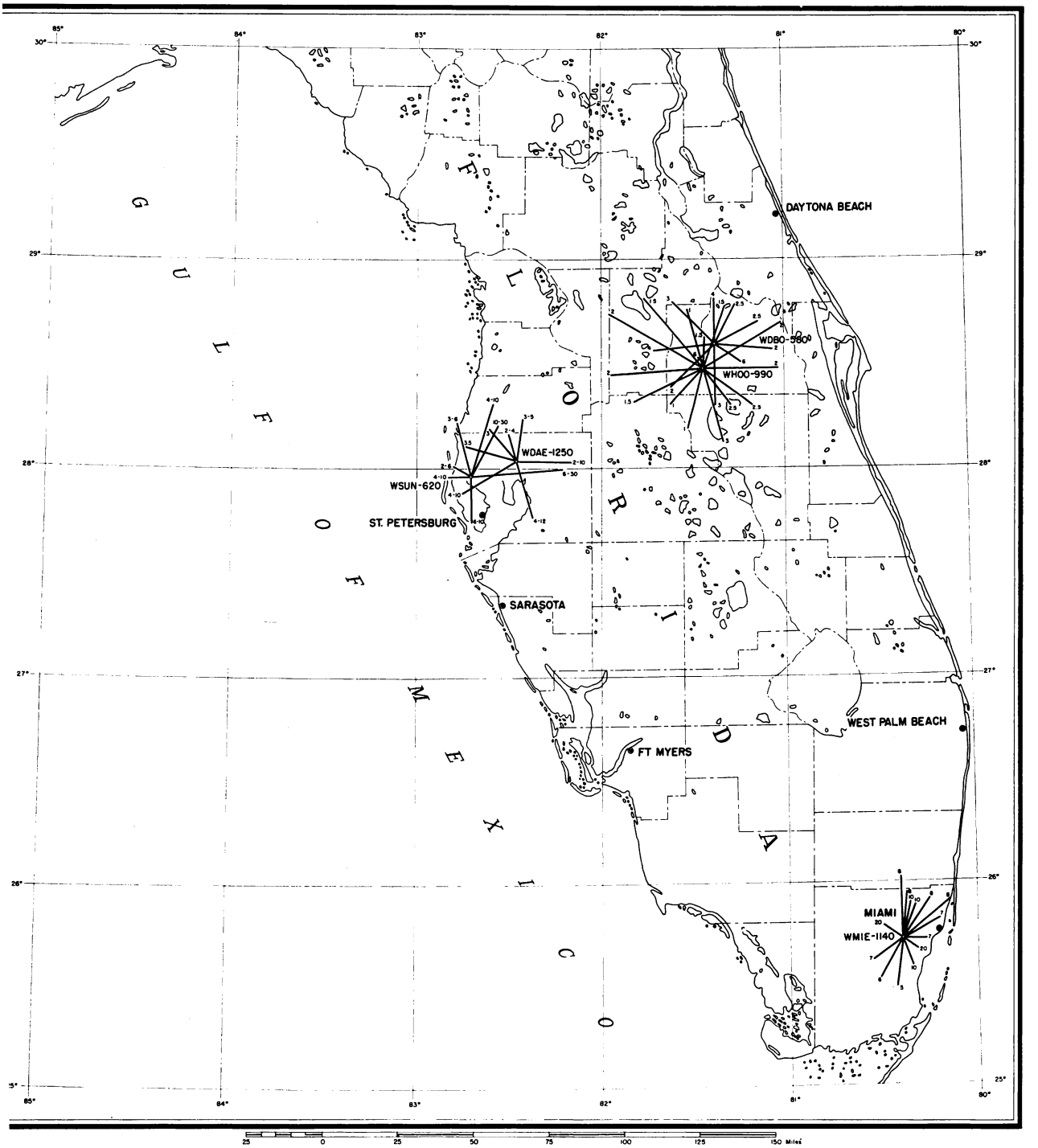
MAP 47a.



MAP 47b.



Map 48a.



MAP 48b.

U. S. GOVERNMENT PRINTING OFFICE: O—1954